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Making Astronomy fun

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f=1000mm d=114mm. Standard 1.25” eyepiece fitting. 12mm (83x) and 20mm (50x) eyepieces included.

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Discover the wonders of the universe

Space and astronomy in 2014 has been as dramatic a year as we can remember: a slew of planetary, lunar and other annual celestial events aside, we've seen an extremely rare occultation of a bright star by a large asteroid in March, the southern hemisphere experienced an annular solar eclipse in April and the BICEP2 team in Antarctica got us all punching the air with their detection of a Big Bang signal. Even if doubt was cast over this 'direct evidence of cosmic inflation' with later independent scrutiny, it made front-page news and briefly raised the profile of space research, which is never a bad thing.

This year also saw work begin on the European Southern Observatory's super-telescope, as the top of a Chilean mountain was blown off in preparation for the site of ESO's European Extremely Large Telescope (E-ELT). The Cassini spacecraft confirmed what scientists have suspected for some time – that the icy crust of Saturn's moon Enceladus sits atop a vast water ocean. The Mars rover Curiosity arrived at Mount Sharp after two years meandering through Gale Crater, and we've had two incredible comet events: Siding Spring narrowly missed Mars in October, blazing a trail across the sky and sending our Martian orbiters scuttling for safety around the other side of the Red Planet. Then, most recently, the Rosetta mission had us on the edge of our seats as the success of 25 years of planning and development hinged on a three-day window, in which scientists had to make the best of a potentially disastrous situation.

With a total solar eclipse to look forward to in March 2015, next year promises not to disappoint either. Happy Christmas!

Ben Biggs
Editor

> "I asked them: 'Would you like to be on the Moon with me?' My children said: 'Yes sir, we sure would!'"
>
> **Charles Duke, Apollo 16 pilot**

Crew roster

Giles Sparrow

■ Touring the mighty natural power station of our nearest star, Giles explains the science of the Sun

Gemma Lavender

■ What celestial sights can we look forward to next year? See Gemma's 2015 stargazing guide

Paul Cockburn

■ Paul's debut for **AAS** is a fascinating article on the field of space archaeology

Laura Mears

■ Get up to speed on Mars with Laura's 25 biggest Martian discoveries on page 16

An artist's impression of Comet Siding Spring, as it streaked past Mars in October

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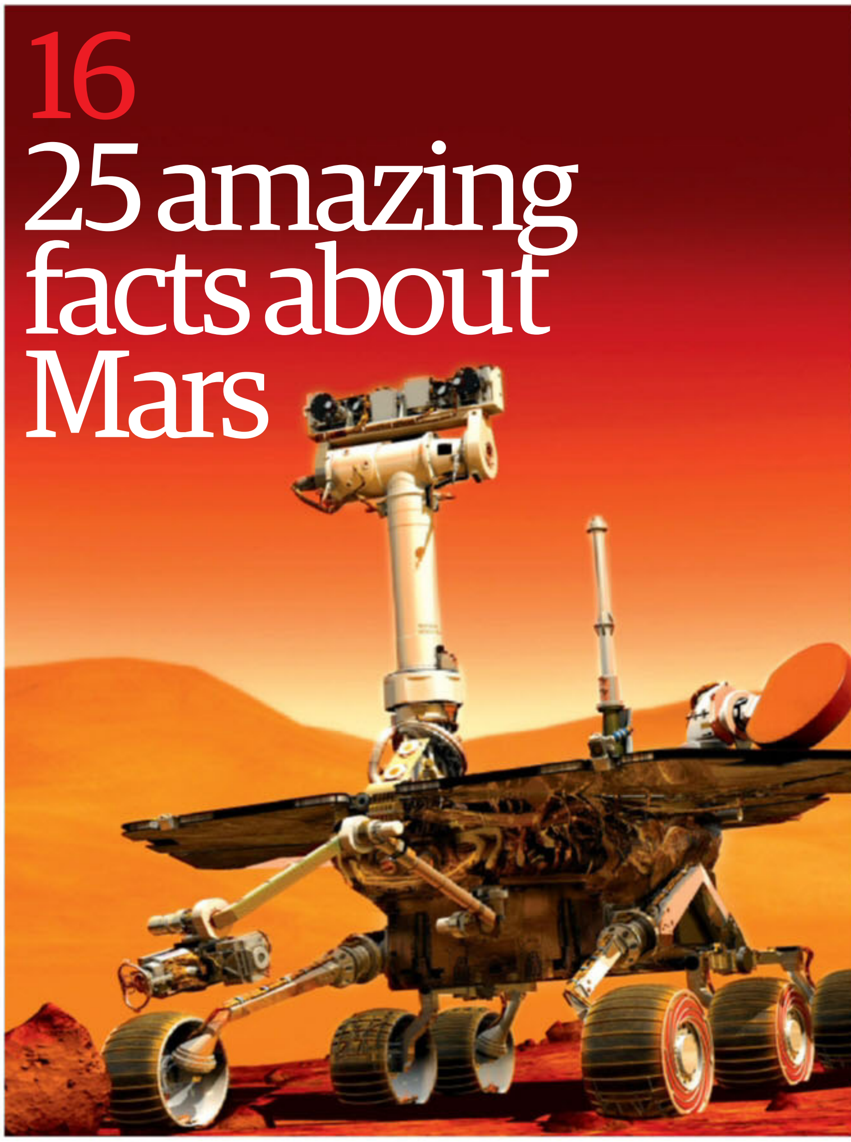

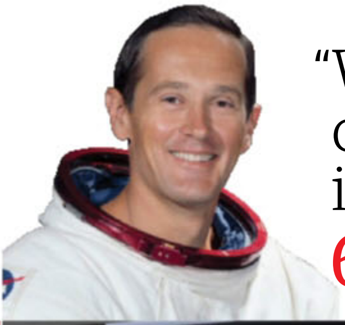

"We were supposed to go outside right after we landed... instead, we went to sleep"

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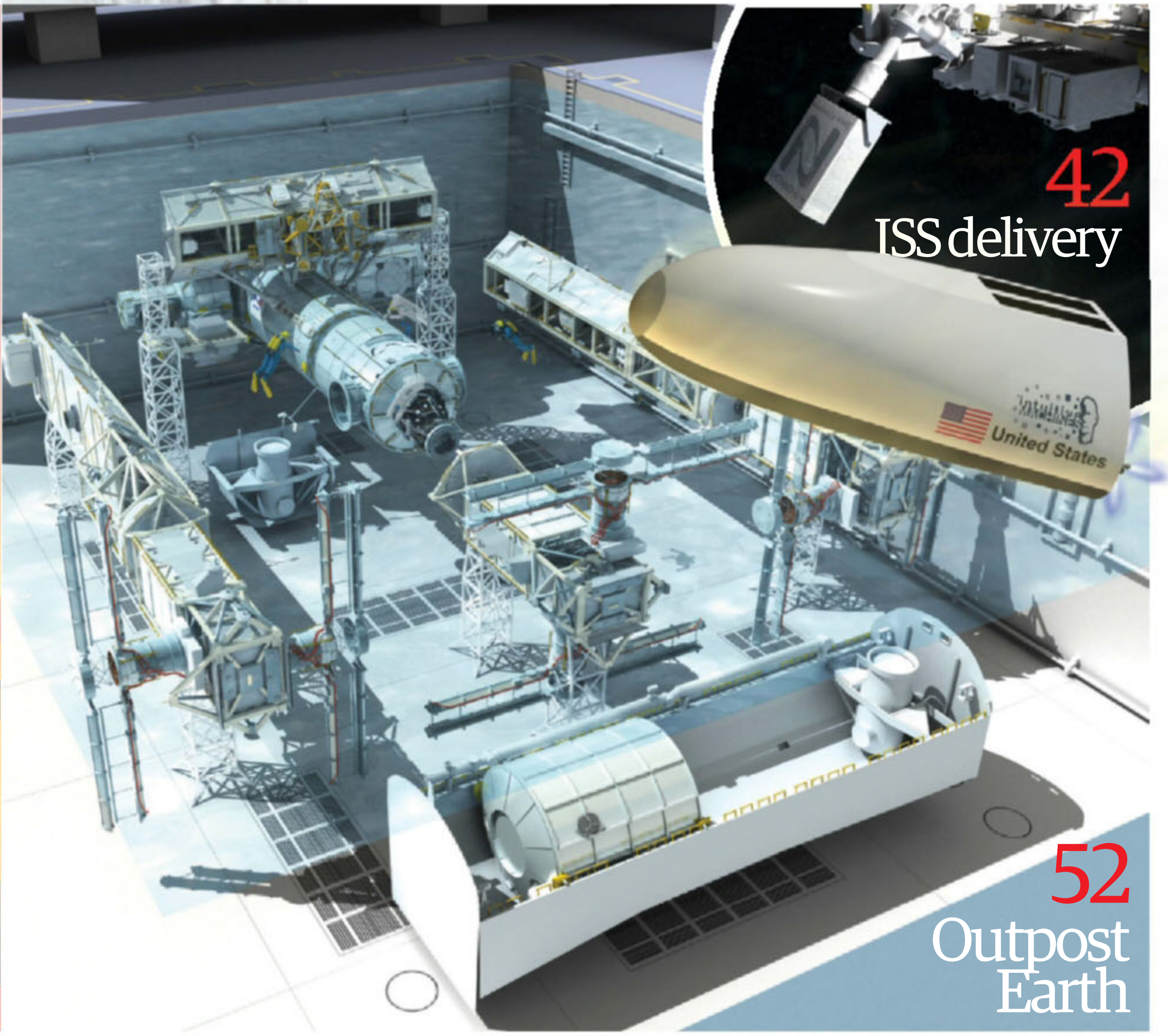

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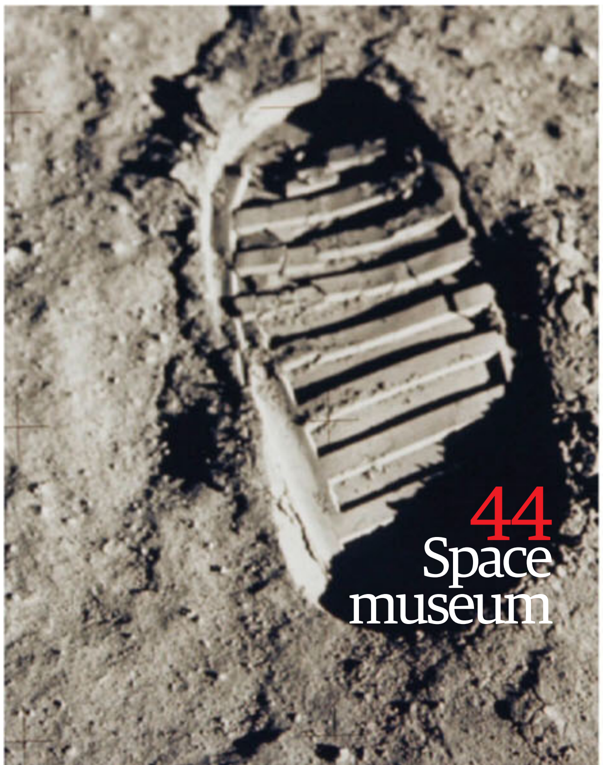

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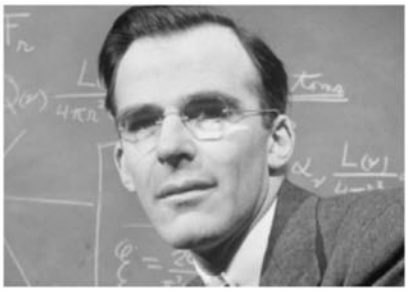

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The man who pioneered telescopes in space

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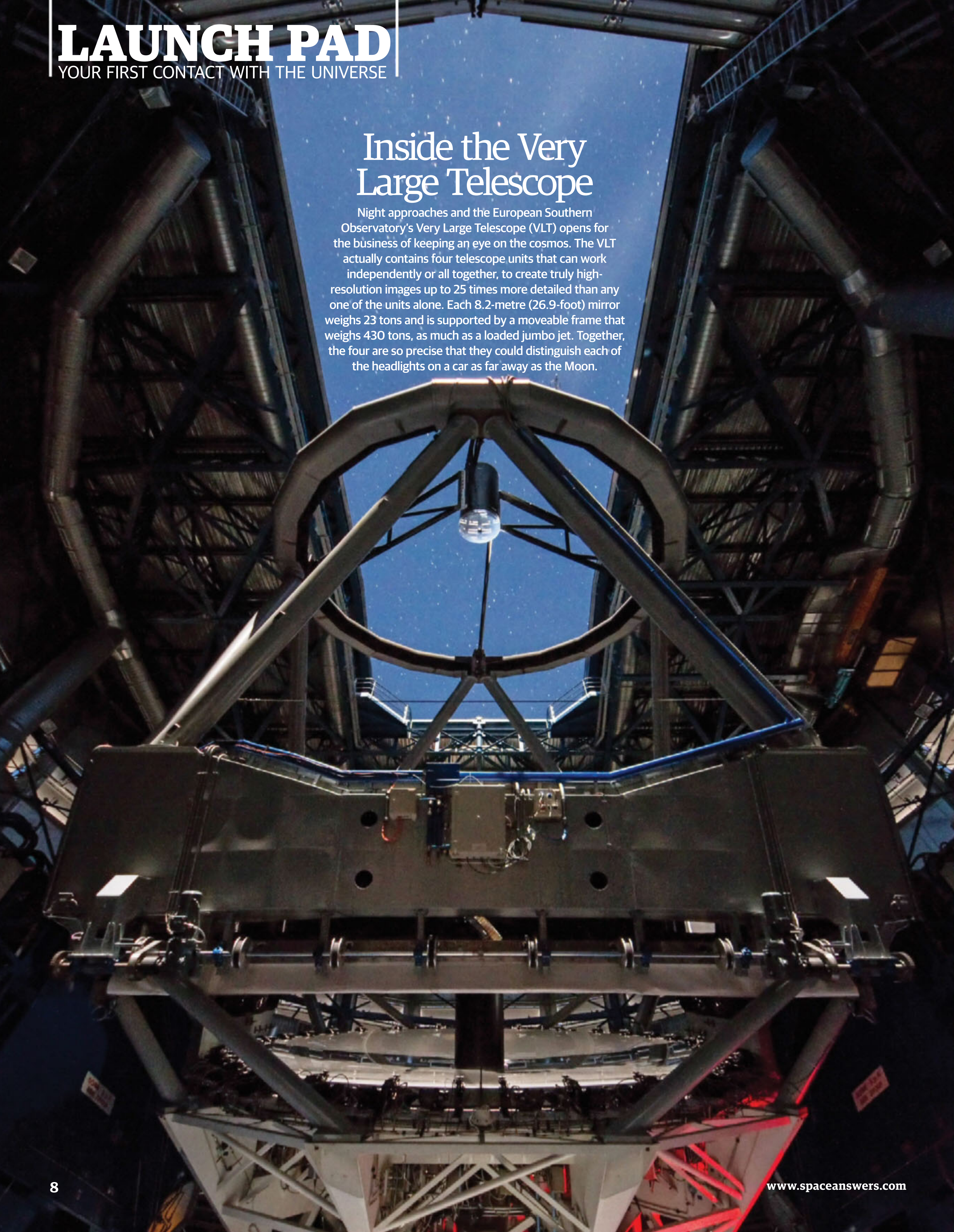
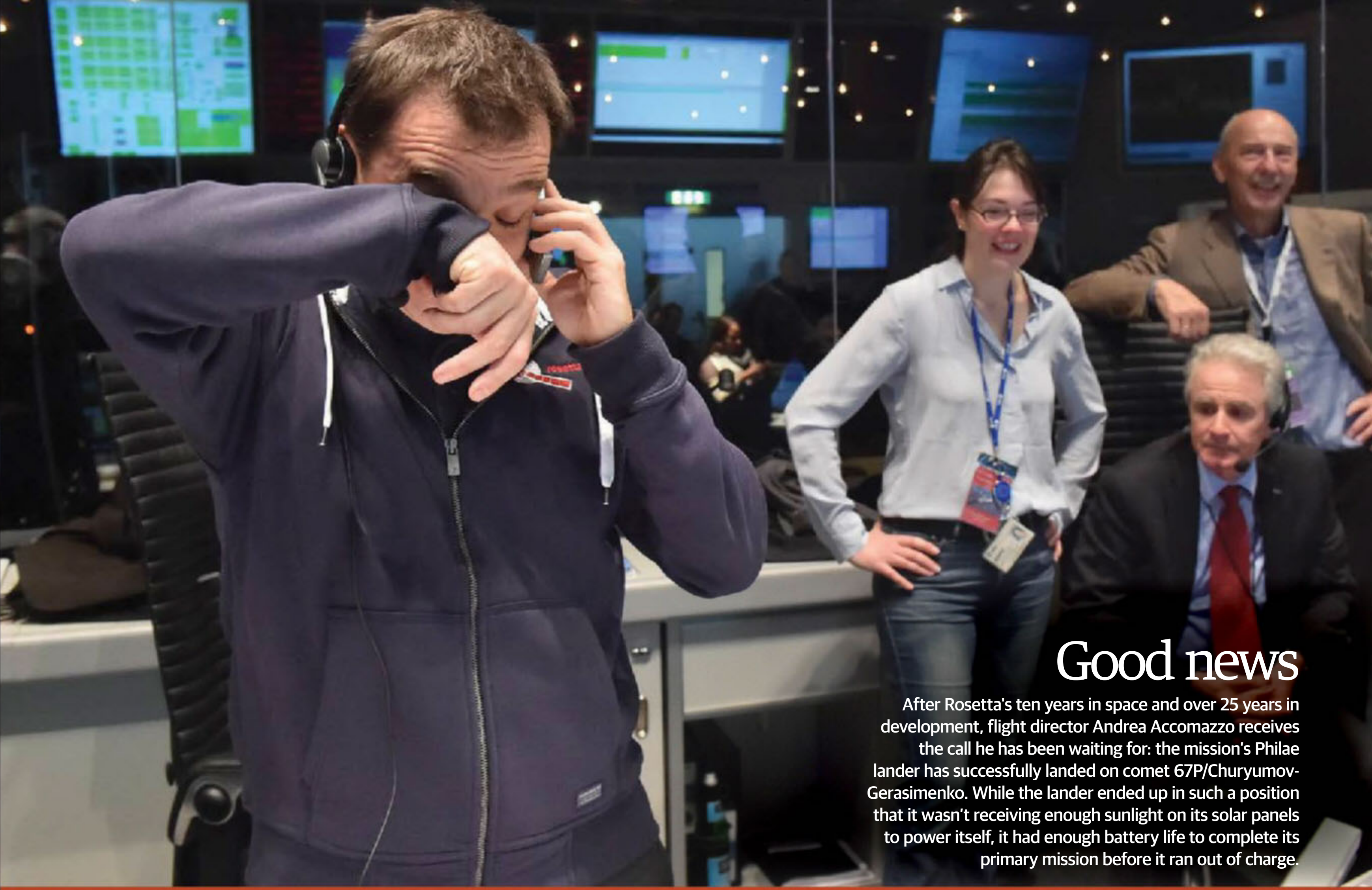
100-million-year collision

This famous space object is actually two galaxies in the process of colliding. It's a typically enormous event for the cosmos: galaxies NGC 4038 and NGC 4039 are ejecting antenna-like tails of dust, gas and stars thousands of light years long, as they interact with each other in a collision that has taken 100 million years so far and continues today. Within the next 400 million years, they should become a single galaxy.



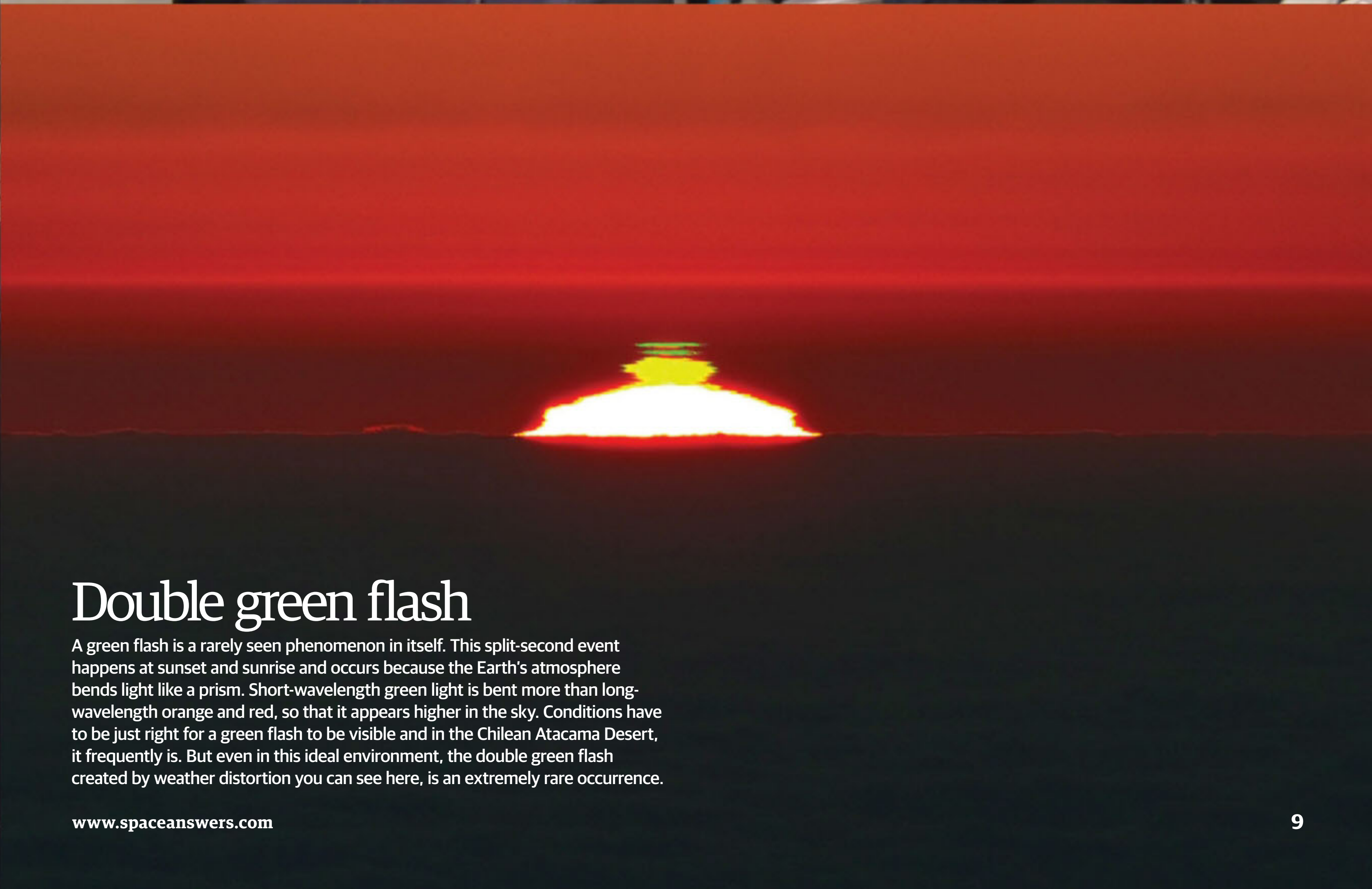
Inside the Very Large Telescope

Night approaches and the European Southern Observatory's Very Large Telescope (VLT) opens for the business of keeping an eye on the cosmos. The VLT actually contains four telescope units that can work independently or all together, to create truly high-resolution images up to 25 times more detailed than any one of the units alone. Each 8.2-metre (26.9-foot) mirror weighs 23 tons and is supported by a moveable frame that weighs 430 tons, as much as a loaded jumbo jet. Together, the four are so precise that they could distinguish each of the headlights on a car as far away as the Moon.



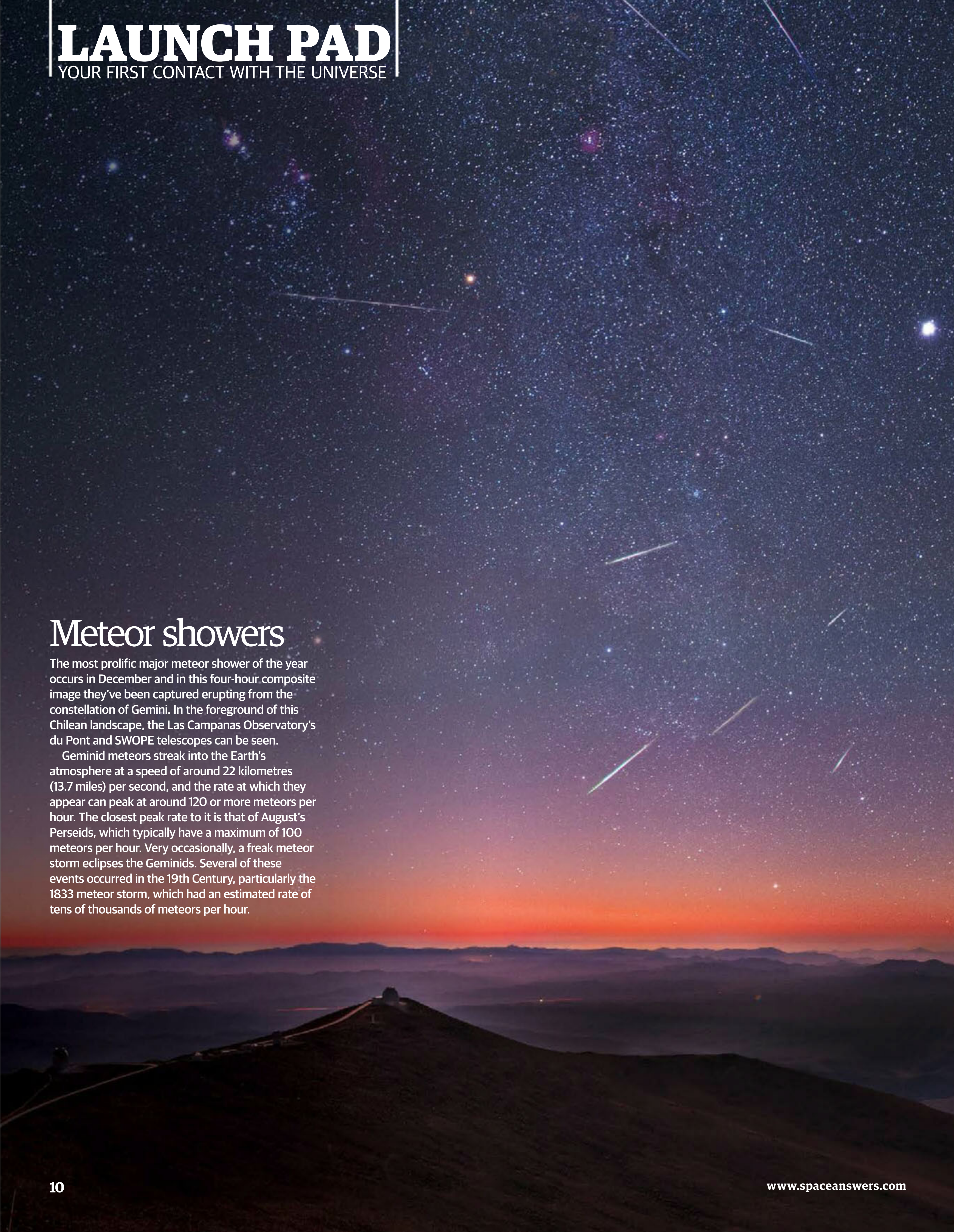
Good news

After Rosetta's ten years in space and over 25 years in development, flight director Andrea Accomazzo receives the call he has been waiting for: the mission's Philae lander has successfully landed on comet 67P/Churyumov-Gerasimenko. While the lander ended up in such a position that it wasn't receiving enough sunlight on its solar panels to power itself, it had enough battery life to complete its primary mission before it ran out of charge.



Double green flash

A green flash is a rarely seen phenomenon in itself. This split-second event happens at sunset and sunrise and occurs because the Earth's atmosphere bends light like a prism. Short-wavelength green light is bent more than long-wavelength orange and red, so that it appears higher in the sky. Conditions have to be just right for a green flash to be visible and in the Chilean Atacama Desert, it frequently is. But even in this ideal environment, the double green flash created by weather distortion you can see here, is an extremely rare occurrence.



Meteor showers

The most prolific major meteor shower of the year occurs in December and in this four-hour composite image they've been captured erupting from the constellation of Gemini. In the foreground of this Chilean landscape, the Las Campanas Observatory's du Pont and SWOPE telescopes can be seen.

Geminid meteors streak into the Earth's atmosphere at a speed of around 22 kilometres (13.7 miles) per second, and the rate at which they appear can peak at around 120 or more meteors per hour. The closest peak rate to it is that of August's Perseids, which typically have a maximum of 100 meteors per hour. Very occasionally, a freak meteor storm eclipses the Geminids. Several of these events occurred in the 19th Century, particularly the 1833 meteor storm, which had an estimated rate of tens of thousands of meteors per hour.

© NASA; ESA; ESO, Yuri Beletsky

"I'm feeling a bit tired, did you get all my data?"

@Philae2014

Rosetta's Philae lander loses power after it touches down on comet 67P, but still makes space history

The European Space Agency's Philae probe has soft-landed on a comet - known as 67P/Churyumov-Gerasimenko - for the first time. However, harpoons designed to anchor Philae to the surface did not deploy, and it bounced twice before coming to rest at an awkward angle in the shade of a cliff.

Without adequate light to the solar panels the probe was in trouble, but after a tense few days it managed to complete its primary scientific mission. The lander then tweeted, "I'm feeling a bit tired, did you get all my data? I might take a nap", before going into hibernation mode as its batteries gradually bled dry.

Philae's panoramic camera returned 360-degree shots of its final resting place, revealing how close it is to a rocky wall, and showing one of its landing legs sticking upwards into space. The planned landing site would have provided an estimated seven hours of sunlight to the solar panels for every 12.4-hour day on the comet, but with just 1.5 hours of sunlight each day at its current location, Philae was running out of battery fast. At the time of writing, the exact location of the lander is still unknown, although scientists continue to scour the high-resolution images captured by the orbiter and the lander for clues.

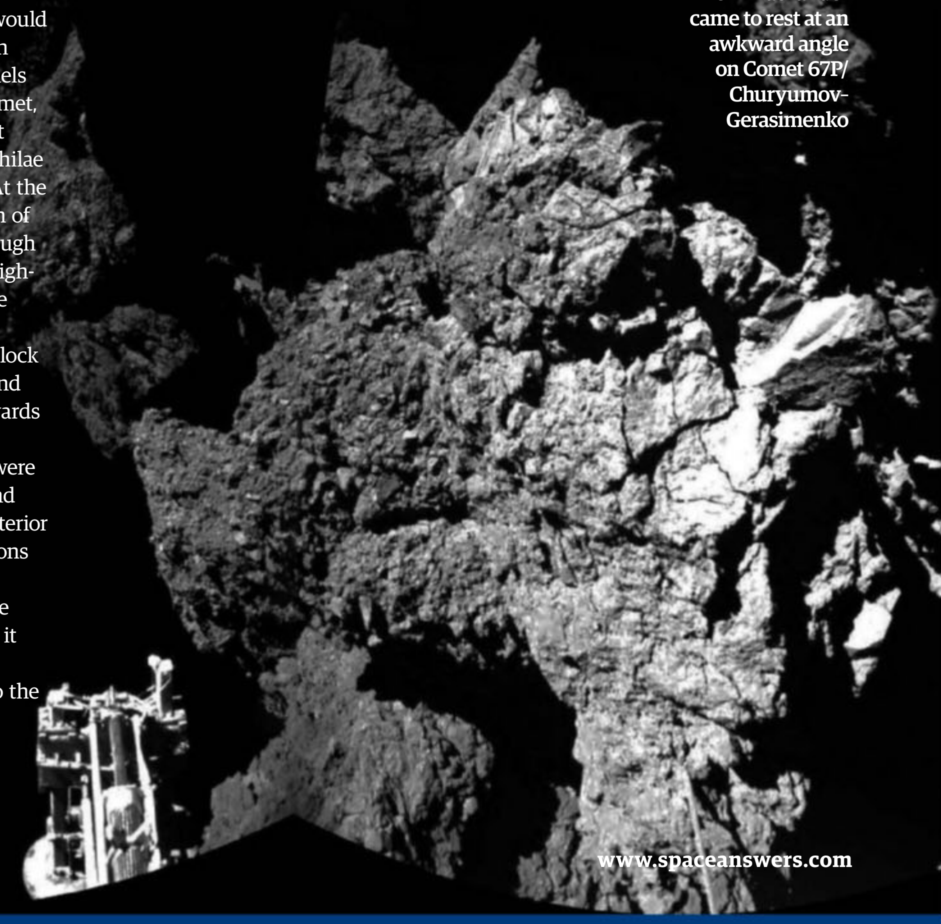
The team worked around the clock to maximise the data gathered, and as the batteries started to fail towards the end of the mission, all of the scientific experiments on board were deployed, including a hammer and drill to sample the surface and interior of the comet. These risky operations could have dislodged the lander, but luckily it held firm, and before its energy supply finally gave out it managed to return all of the data back to the orbiter and then on to the scientists waiting on the ground.

Before Philae went to sleep, the team managed to tilt the craft, moving it upwards by four centimetres (1.6 inches) and turning it through 35 degrees. It is hoped that as it nears the Sun, there might be enough power generated by the repositioned panels to wake it. If not, the mission has still been a huge success, returning incredible high-resolution images of the surface of a comet, and a stream of data that could bring clues about the origins of the Solar System, and the involvement of comets in bringing water and organic molecules to early Earth.

The Rosetta spacecraft made an incredible ten-year journey to Comet 67P/Churyumov-Gerasimenko. It travelled over 6.4 billion kilometres (4 billion miles) before dropping the Philae lander onto a target that measures just four kilometres (2.5 miles) in diameter, and is moving at speeds of up to 135,000 kilometres (84,000 miles) per hour.

Rosetta continues to orbit the comet, and over the coming months will complete several more flybys.

> "A stream of data could bring clues about how comets could have brought water to early Earth"



The Philae lander came to rest at an awkward angle on Comet 67P/Churyumov-Gerasimenko

Tweeting probe

12th November 2014

Philae Lander
@Philae2014
Finally! I'm stretching my legs after more than 10 years. Landing gear deployed! #CometLanding

13th November 2014

ESA Rosetta Mission
@ESA_Rosetta
.@WilliamShatner touchdown confirmed for away team @philae2014, captain!

ESA Rosetta Mission
@ESA_Rosetta
Show-off! ;) MT @Philae2014: Yesterday was exhausting! I actually performed 3 landings, 15:33, 17:26 & 17:33 UTC. #CometLanding

14th November 2014

ESA Rosetta Mission
@ESA_Rosetta
.@Philae2014 you're in a shadow? How am I supposed to spot you there?! Our teams working hard to find you :)

Philae Lander
@Philae2014
Back to work! I'm now drilling into the surface of #67P... I'll give you updates as soon as I can! #CometLanding

ESA Rosetta Mission
@ESA_Rosetta
Let's see if you can get some more sun @philae2014! MT @esaoperations: Lander performing 'lift & turn' of body on landing gear #CometLanding

ESA Operations
@esaoperations
Communication link with @Philae2014 remains good. Teams working to download as much data as possible before battery depleted #cometlanding

ESA Rosetta Mission
@ESA_Rosetta
.@Philae2014 S'ok Philae, I've got it from here for now. Rest well...

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Rogue stars are kicked out into space as their parent galaxies collide

Half of all stars are rogue

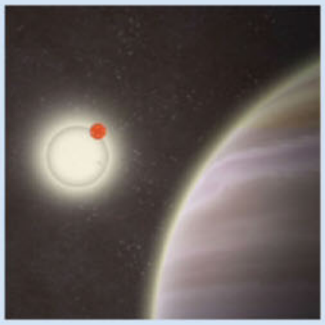
As many as 50 per cent of all the stars in the universe drift alone through space, kicked out of their parent galaxies during violent collisions

According to a study published in *Science* magazine, as many as half of all stars in our universe do not belong to galaxies. The extragalactic background light (EBL) is a fog that covers the universe, representing all of the light emitted by stars throughout history. It was originally thought that disturbances within this background might represent primordial galaxies and black holes, formed at the beginning of the universe, but new information from the CIBER detector suggests otherwise.

An international team headed by scientists at the California Institute of Technology and the University of California developed the Cosmic Infrared Background ExpeRiment (CIBER) detector to study the EBL. They expected to see the light of the ancient galaxies dim and red after years of travel through space to reach the Earth, but the emissions were much bluer than expected, indicating the presence of young stars.

If all of the bright blue light is added together, it equates to around the same amount of light emitted by all of the galaxies combined, indicating that there might be as many stars outside galaxies as there are inside. It is thought that these lonely rogue stars were kicked out of the parent galaxies during the gravitational turmoil of violent collisions.

This new finding, though still currently being debated in the scientific community, could help to explain a problem that has been puzzling astronomers, known as the photon underproduction crisis. The ultraviolet light emitted by stars is energetic enough to ionise hydrogen gas, but the amount of ionised hydrogen in galaxies far exceeds that which would be predicted given the number of stars inside. If as many rogue stars have been kicked out as predicted, it could help to explain where some of the missing ultraviolet light has gone. ●



Kepler-64b, a four-star planet, was discovered by the Planet Hunters project in 2012

Citizen scientists find a weird new exoplanet

Amateur scientists have spotted another exoplanet in among data captured by NASA's Kepler satellite. Named PH3c, the low-density planet is around four times the mass of Earth, and thought to have a hydrogen and helium atmosphere.

The planet was picked up as part of the Planet Hunters project, launched in 2010 to recruit citizen scientists to help analyse data collected by NASA's Kepler satellite. The telescope is hunting for planets in other systems by measuring the brightness of stars every 30 minutes. As planets pass in front of their parent stars, they cast a shadow, causing the light to dim, and allowing an automated system to identify likely exoplanet candidates.

The automated system is good at picking up planets with a regularly timed orbit, but for planets with stranger orbits, the signs can sometimes be missed. The transit of PH3c around its star takes 66 days, but varies by up to ten hours, and the automated analysis failed to identify it. However, humans are much better at recognising patterns than machines, and volunteers were able to pick it out of the data.

Over 300,000 volunteers help with the project so far, and PH3c is the third confirmed planet to be identified by Planet Hunters. ●

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Google rents out NASA hangar

Google's Planetary Ventures has signed a 60-year lease on Moffett Federal Airfield, including the historic Hangar One. It aims to invest $200 million to restore the site, and plans to use it for research and development of space exploration and aviation.

Crowdfunding could take Britain to Moon

Kickstarter project Lunar Mission One aims to send a robotic drilling mission to the Moon. The project has already received support from leading scientists.

Russia to build a new space station

Russian newspaper *Kommersant* has reported that Russia may be planning to build a new space station in 2017, allowing increased visibility over the Russian territory and enabling testing of rockets bound for the Moon.

3D printer installed on the ISS

The first microgravity 3D printer has been installed on the International Space Station. The printer, developed by Made In Space, will now be used for a series of tests to determine the effectiveness of 3D printing in space.

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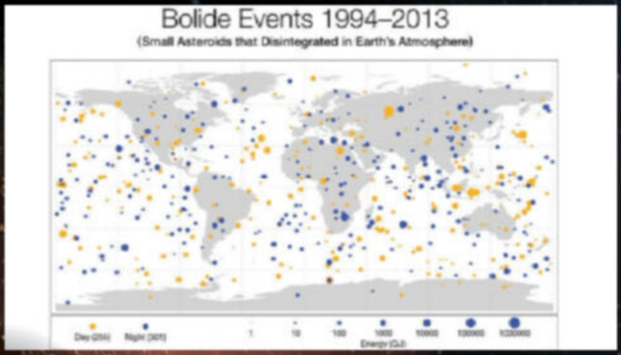


NASA's bolide event map charts 20 years of large fireballs

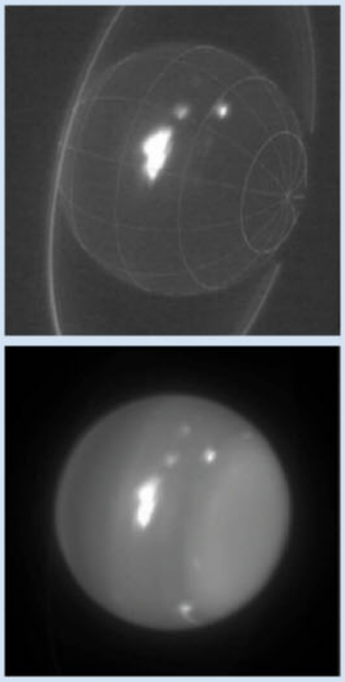
NASA makes asteroid fireball map

Between 1994 and 2013, at least 556 asteroids collided with Earth's atmosphere, creating fireballs

Using data gathered by early warning satellites belonging to US Defence, scientists at NASA's Jet Propulsion Laboratory in California have created a map showing 556 asteroid fireballs that struck Earth's atmosphere over the last 20 years. The data was gathered between 1994 and 2013, and covers asteroids ranging in size from one metre (3.3 feet) - the smallest size to count as an asteroid - all the way up to the 20-metre (66-foot) Chelyabinsk meteoroid that exploded in midair above Russia in 2013.

These fireballs, which are known as bolide events, are the result of asteroids burning up on atmospheric entry as they careen towards the Earth's surface. Each impact released between one and 1 million gigajoules of energy, equivalent to 0.2 and 240,000 tons of TNT. According to the data, an asteroid fireball occurs every two weeks on average, providing a clear demonstration of the protection afforded by Earth's atmosphere.

It is the largest data set of its kind, but did not show anywhere near all of the impacts occurring in that period. According to NASA, the Earth is struck by more than 100 tons of space dust every day, with larger impacts happening more infrequently. A car-sized object collides with Earth around once a year, while a disastrous impact happens every few million years.



Summer storms (shown here as bright spots) on Uranus happen every 42 years, but are seven years late

Unexplained storms on Uranus

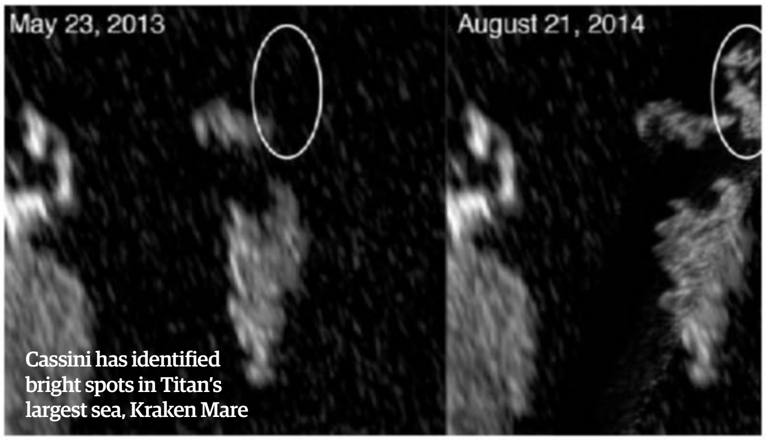
The ice giant Uranus is experiencing its summer storms unusually late this year, and, at present, the bright spots in its atmosphere are visible with low-powered telescopes from Earth. These strange storms were first spotted in August by a team from the University of California, Berkeley at the Keck Observatory in Hawaii, and, since then, amateurs across the world have turned their telescopes towards the planet, excited by the unprecedented opportunity to view detail on a usually hazy ice giant.

Unlike Earth, Uranus is not heated from within, and its weather is driven solely by the heat of the Sun. Summer happens only once every 42 Earth years on Uranus, and scientists would have expected the weather to have been strongest in 2007, when Uranus experienced its equinox. However, the storms are seven years late and, at a press conference in November, team leader Imke de Pater admitted that they have "no idea" what is happening.

Strange spots appear on Titan

Cassini spacecraft has taken pictures of a mysterious bright spot in Titan's largest sea, Kraken Mare

NASA's Cassini spacecraft has captured images of a strange new object in the Kraken Mare sea on Saturn's largest moon, Titan. The object is apparently floating in the liquid ocean and has appeared since the last pictures were captured in May.



Cassini has identified bright spots in Titan's largest sea, Kraken Mare

The feature is similar to one spotted in July 2013 in Titan's smaller hydrocarbon sea Ligeia Mare, dubbed the 'Magic Island'. The strange objects are thought to be bubbles, waves, or even solids floating on top of, or just beneath, the surface.

The Cassini spacecraft flew past Saturn's Titan on 21 August, capturing images with its synthetic aperture radar (SAR) of the 400,000-square-kilometre (154,440-square-mile) sea of liquid methane and ethane near its northern pole.

It also probed the depths of Kraken Mare using its on-board radar instrument. Nearer to the coast, the depth was measured at around 20 to 35 metres (66 to 115 feet), before dropping off in a steep slope. Further from the coast, no signals were bounced back from the sea floor, indicating that either the radar energy was absorbed by the methane and ethane before it could hit the bottom, or that the deepest parts of Kraken Mare extend more than 200 metres (656 feet) below the surface.

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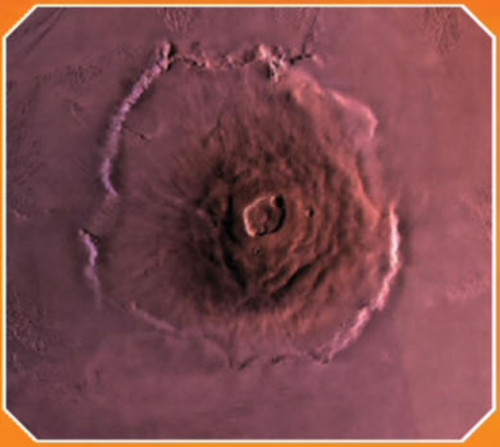
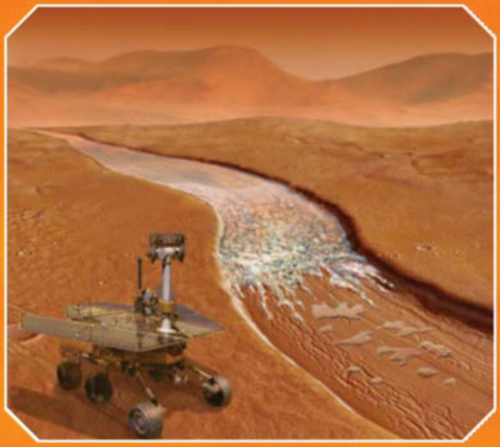
MARS
25 amazing discoveries

It is almost 50 years since the first spacecraft flew past Mars and, in that time, we have learnt a huge amount about our mysterious red neighbour

Written by Laura Mears



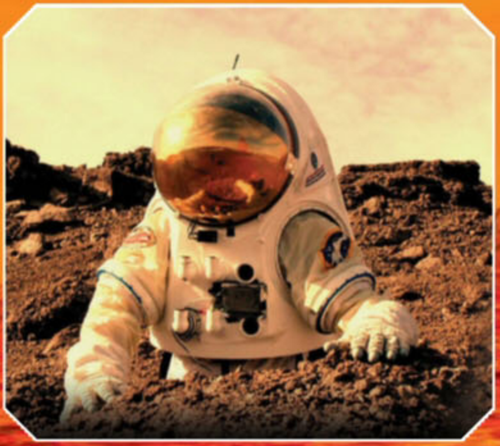
A MASSIVE VOLCANO



ITS ANCIENT WATERWAYS

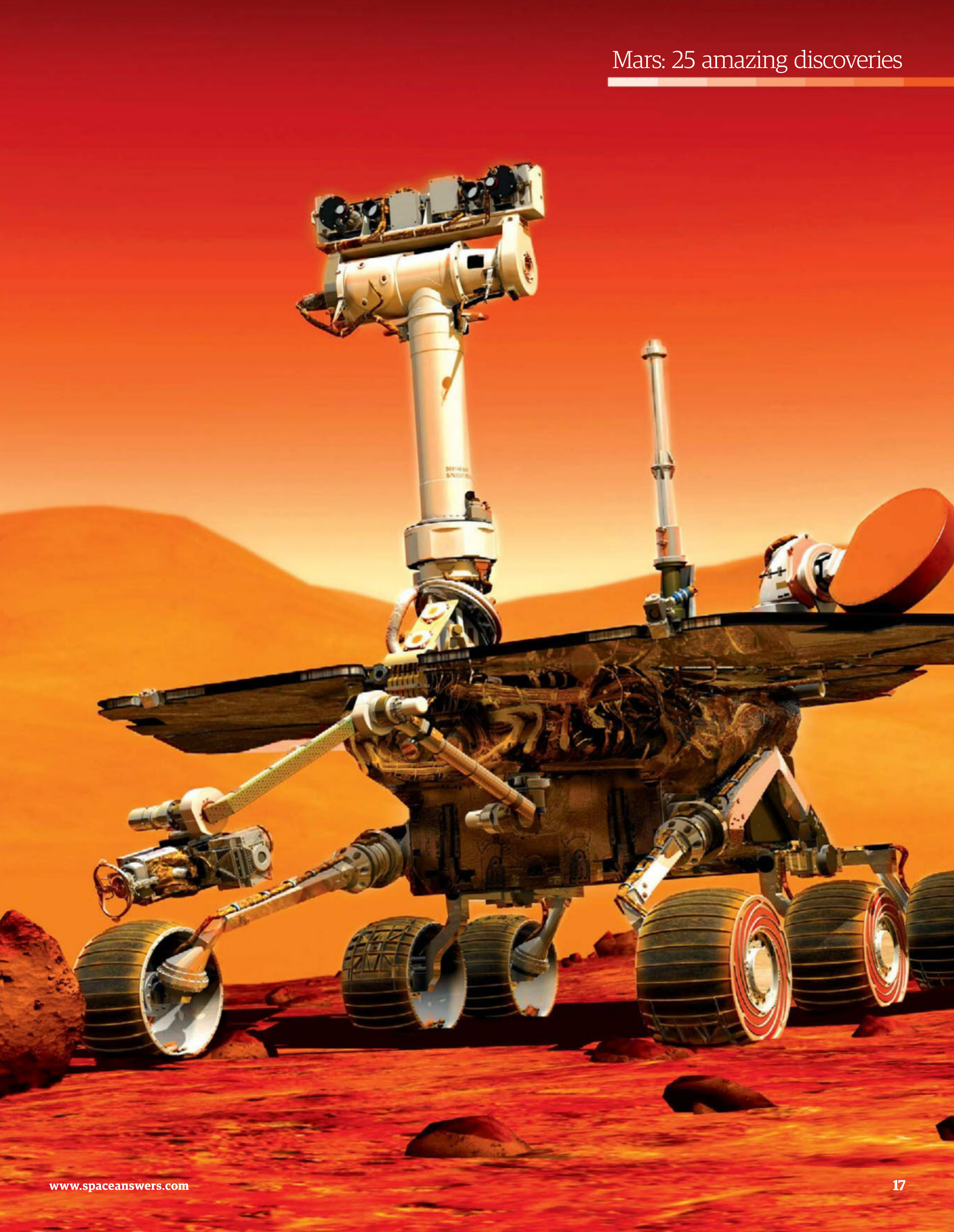
THE MELTING POLAR ICE CAPS

A NEAR-MISS



THE DANGERS OF EXPLORATION

ITS VIOLENT HISTORY



Astronomer Schiaparelli observed 'channels' on Mars

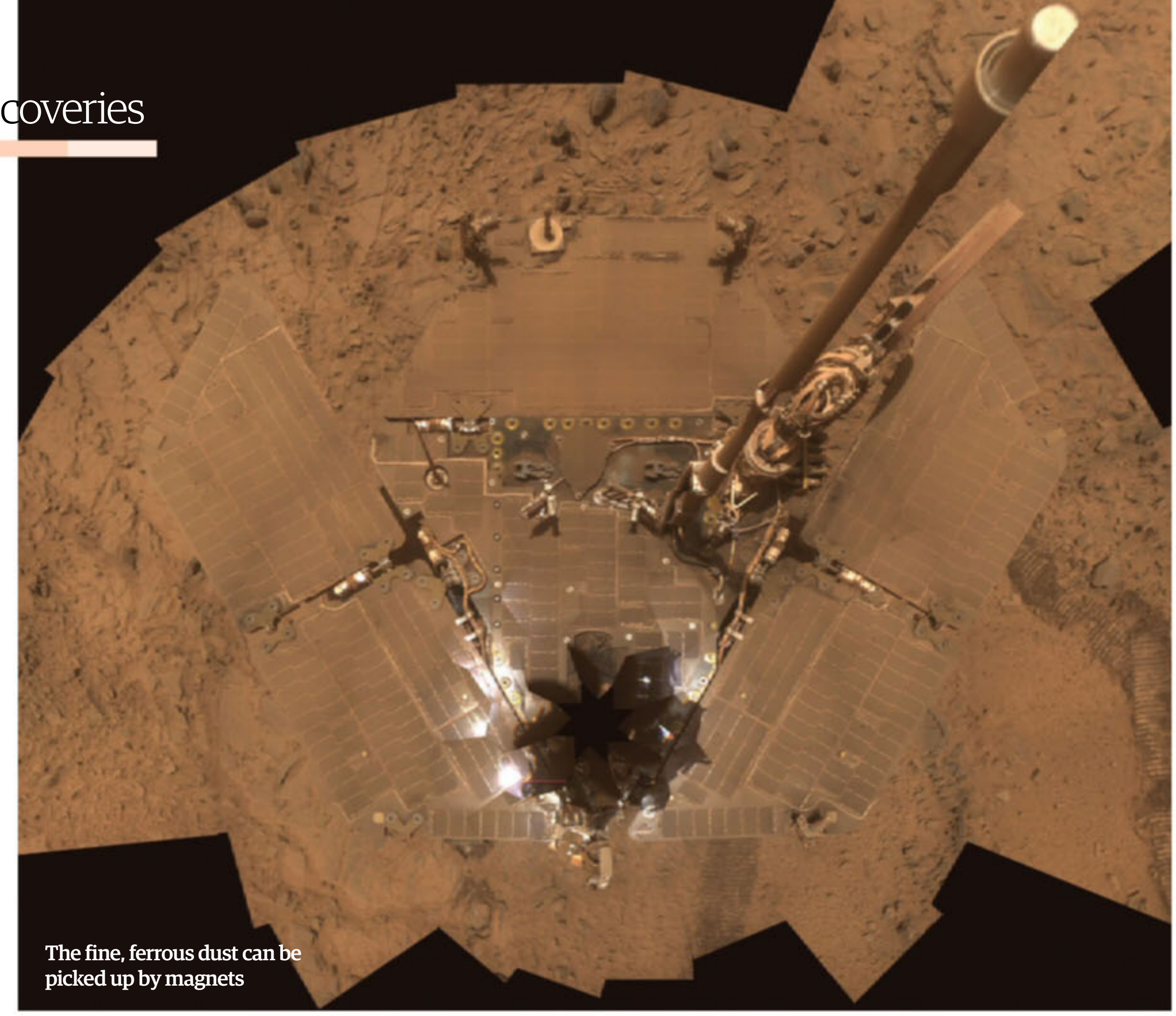
1 Mars looks like a dead planet

Since the invention of the telescope in the 1600s, astronomers have been fascinated by the surface of Mars. It is too far away to resolve from the Earth, and the atmospheres of both planets interfere with the passage of light, but they noticed dark and light patches that moved as the year passed, and speculated that they might belong to clouds, seas and even forests.

In the 19th Century, Italian astronomer Giovanni Schiaparelli described a series of channels that he saw in the surface of the planet, imagining that there might be water on the surface, but a mistranslation of the Italian word 'canali' led American scientists, most notably Percival Lowell, to believe that the Red Planet was actually covered in canals, possibly built by an intelligent life form.

Hopes of an Earth-like planet were dashed when NASA's Mariner 4 captured the first ever close-up images of the surface during a flyby in 1965. The 22 stills showed craters, reminiscent of the scarred surface of the Moon, and revealed the planet to be a barren waste covered in red dust and rubble. Measurements taken by the onboard instruments detected no magnetic field, and barely any atmosphere.

For years after, scientists thought Mars was a dead planet, whose geological activity stopped billions of years ago. But subsequent missions revealed that there's much more to Mars than meets the eye.



The fine, ferrous dust can be picked up by magnets

2 Martian dust is magnetic

The Red Planet owes its distinctive colouration to iron, which was detected in high quantities in the soil by the Viking landers in 1976. Its surface is coated in a fine layer of dust, which after billions of years of winds and storms has been ground down to a consistency finer than talcum powder. The Imager for Mars Pathfinder (IMP), attached to the Carl Sagan Memorial Station, which landed in 1997, used the difference in atmospheric brightness throughout the day to measure the size of the airborne dust particles, revealing that on average, they measure about three microns in diametre.

In 2004, NASA's Spirit rover carried permanent magnets to the surface of the planet to probe the dust further, confirming that almost all of the dust on Mars is magnetic, whether in the air or on the ground. Two angled magnets captured particles from the atmosphere, revealing different oxides of iron; strongly magnetic dark material that is either magnetite or maghemite, plus lighter, less magnetic haematite. The rover also carried a strong magnet near its panoramic camera that repelled the dust, protecting the equipment and ensuring the images remained clear.

Mission Profile

Mariner 4

Launched: 28 November 1964

Arrived at Mars: 14 July 1965

Weight: 260.68kg (574.70lb)

Number of days on/around Mars (in Martian days and Earth days): 1 day/1 day

Current status: Communications terminated in 1967

3 It is home to the tallest mountain in the Solar System

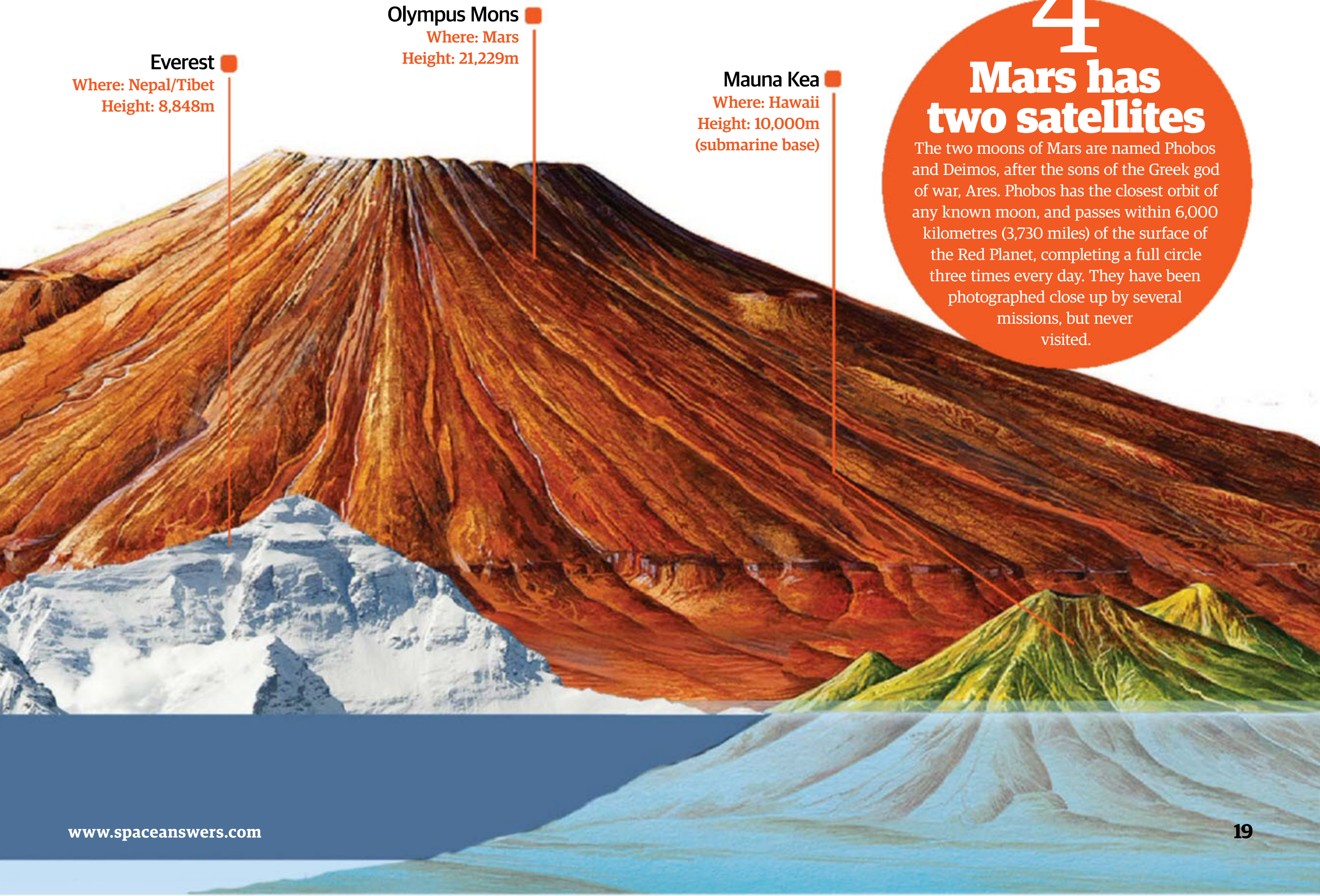
The biggest mountain we know of is nearly three times taller than Everest

The first orbiter to visit Mars was NASA's Mariner 9, tasked with mapping 70 per cent of the planet's surface. However, when it arrived in 1971, the planet was engulfed in a dust storm that completely obscured the view of the ground below, and the orbiter had to wait for several months for the dust to settle.

As the storm subsided, the highest points were revealed first, and four enormous volcanoes started to appear above the sinking clouds. They were large and domed in appearance, and the sides had gentle slopes, reminiscent of the shield volcanoes on Earth.

The lava in shield volcanoes is lower in silica than the lava in stratovolcanoes, making it runnier and more liquid. Instead of spraying outwards, as it escapes through the crust it moves in fluid sheets, and the lava flows travel for great distances across the ground. Over time, a gentle slope builds up as layer upon layer of lava are laid down, resulting in a wide, smooth volcano.

The tallest of the Martian shield volcanoes is Olympus Mons, measuring 624 kilometres (374 miles) across and extending nearly 26 kilometres (16 miles) above the ground. It easily dwarfs every other peak identified in the Solar System to date. For comparison, the tallest volcano on Earth, Mauna Kea in Hawaii, extends 10,000 metres (32,800 feet) above the floor of the Pacific Ocean.



4 Mars has two satellites

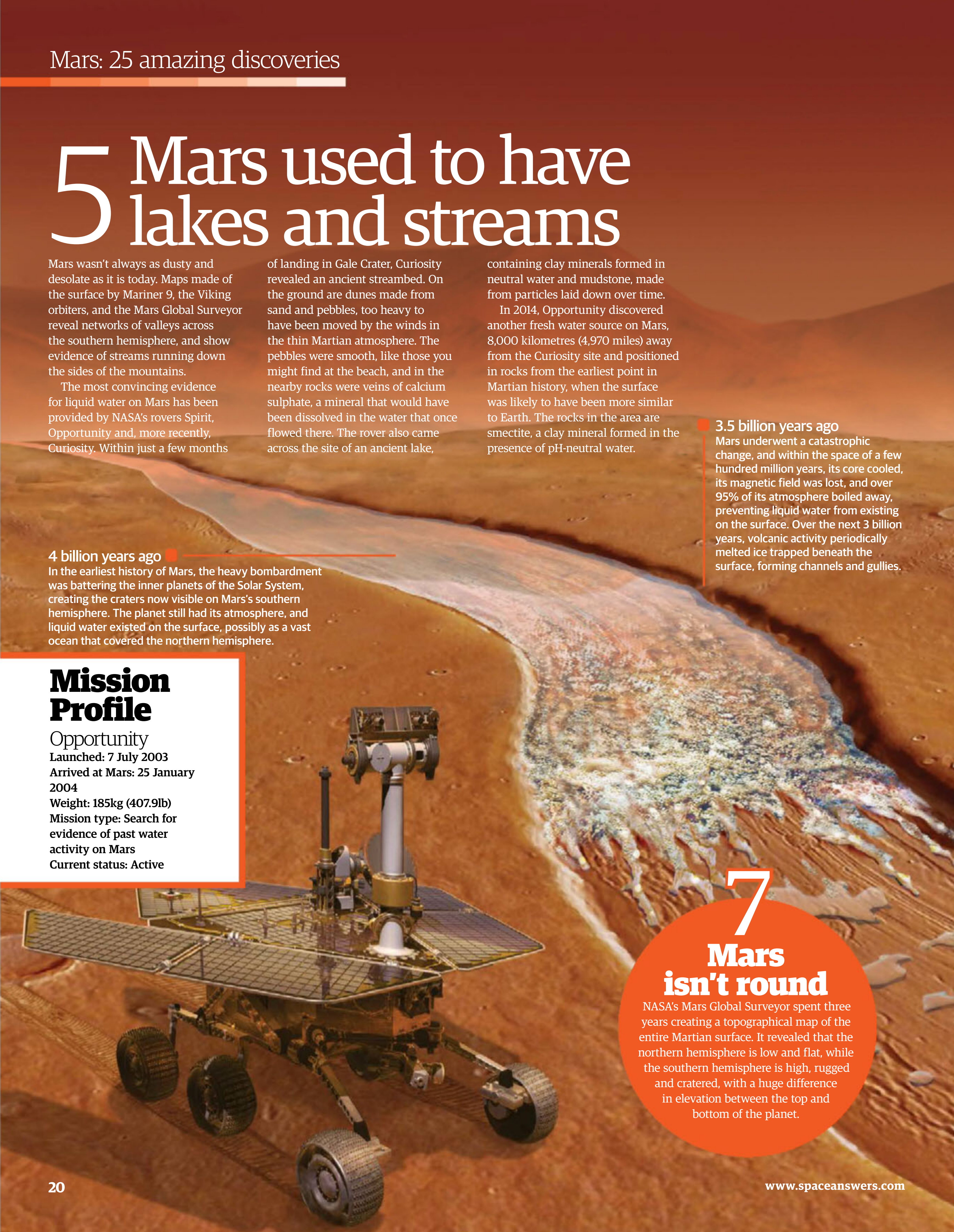
The two moons of Mars are named Phobos and Deimos, after the sons of the Greek god of war, Ares. Phobos has the closest orbit of any known moon, and passes within 6,000 kilometres (3,730 miles) of the surface of the Red Planet, completing a full circle three times every day. They have been photographed close up by several missions, but never visited.

5 Mars used to have lakes and streams

Mars wasn't always as dusty and desolate as it is today. Maps made of the surface by Mariner 9, the Viking orbiters, and the Mars Global Surveyor reveal networks of valleys across the southern hemisphere, and show evidence of streams running down the sides of the mountains.

The most convincing evidence for liquid water on Mars has been provided by NASA's rovers Spirit, Opportunity and, more recently, Curiosity. Within just a few months of landing in Gale Crater, Curiosity revealed an ancient streambed. On the ground are dunes made from sand and pebbles, too heavy to have been moved by the winds in the thin Martian atmosphere. The pebbles were smooth, like those you might find at the beach, and in the nearby rocks were veins of calcium sulphate, a mineral that would have been dissolved in the water that once flowed there. The rover also came across the site of an ancient lake, containing clay minerals formed in neutral water and mudstone, made from particles laid down over time.

In 2014, Opportunity discovered another fresh water source on Mars, 8,000 kilometres (4,970 miles) away from the Curiosity site and positioned in rocks from the earliest point in Martian history, when the surface was likely to have been more similar to Earth. The rocks in the area are smectite, a clay mineral formed in the presence of pH-neutral water.



3.5 billion years ago

Mars underwent a catastrophic change, and within the space of a few hundred million years, its core cooled, its magnetic field was lost, and over 95% of its atmosphere boiled away, preventing liquid water from existing on the surface. Over the next 3 billion years, volcanic activity periodically melted ice trapped beneath the surface, forming channels and gullies.

4 billion years ago

In the earliest history of Mars, the heavy bombardment was battering the inner planets of the Solar System, creating the craters now visible on Mars's southern hemisphere. The planet still had its atmosphere, and liquid water existed on the surface, possibly as a vast ocean that covered the northern hemisphere.

Mission Profile

Opportunity

Launched: 7 July 2003

Arrived at Mars: 25 January 2004

Weight: 185kg (407.9lb)

Mission type: Search for evidence of past water activity on Mars

Current status: Active

7 Mars isn't round

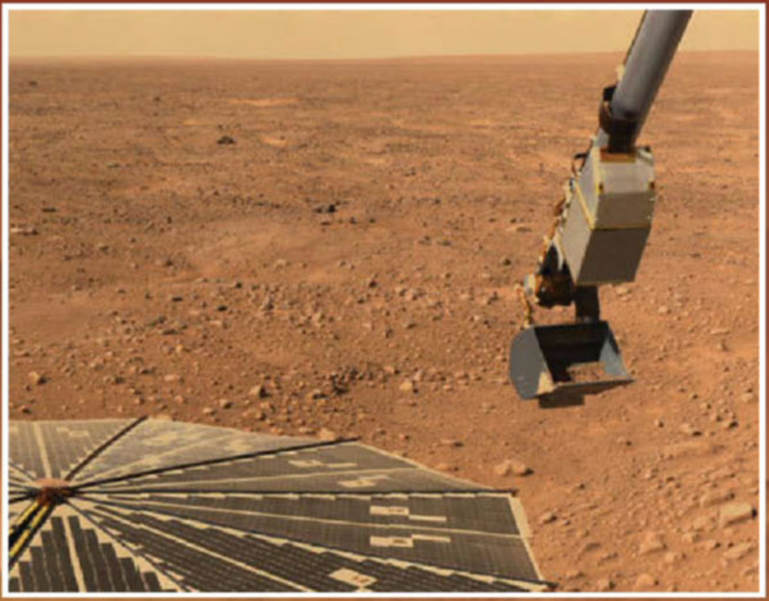
NASA's Mars Global Surveyor spent three years creating a topographical map of the entire Martian surface. It revealed that the northern hemisphere is low and flat, while the southern hemisphere is high, rugged and cratered, with a huge difference in elevation between the top and bottom of the planet.

6 It was once capable of supporting life

The sedimentary rocks laid down over millions of years on the surface of Mars are evidence that liquid water existed for prolonged periods, giving plenty of time for life to have evolved. Following the repeated discovery of water on Mars, NASA switched its focus to searching for signs of life, and the Curiosity rover has been hunting since it landed in 2012.

It has drilled into the sedimentary rocks in a location called Yellowknife Bay, revealing that the minerals beneath contain nitrogen, phosphorous, hydrogen, oxygen, carbon, and sulphur - the building blocks of the biological molecules that make up all life on Earth. On our own planet, microorganisms known as lithoautotrophs (rock eaters) can survive by using inorganic molecules to obtain their energy.

As the climate on Mars changed, the liquid water on the surface became trapped in the soil as permafrost, and today nothing can survive on the surface. The planet is bathed in radiation, battered by solar winds, and the atmosphere is painfully thin. However, on Earth bacteria can survive buried deep in Antarctic permafrost. Scientists are hopeful that if there was once life on Mars, traces will remain in the ice.



Present day

The atmosphere on Mars is thin, and the vapour pressure is low. Any water ice reaching the surface instantly sublimes into vapour and escapes. Much of the water that used to cover the planet is trapped beneath the ground as permafrost, and missions are ongoing to determine whether there is liquid water hidden below.

Mission Profile

Curiosity

Launched: 26 November 2011
Arrived at Mars: 5 August 2012
Weight: 899kg (1982lb)
Mission type: To determine whether Mars could have supported life in the past
Current status: Active

8 A day on Mars is 41 minutes longer than a day on Earth

Mars missions are planned and executed according to Mars time, where a day lasts for 24 hours and 37 minutes (compared to the 23 hours and 56 minutes of an Earth day). Amazingly, this number has been known since 1666, when Giovanni Cassini calculated the spin by watching surface features appear and disappear (he estimated the Martian day length to be 24 hours and 40 minutes).

9 Its gravity is about a third of Earth's

The orbital behaviour of satellites around Mars, both natural and artificial, have revealed that there is 62 per cent less gravity on Mars than there is on Earth. Mars is just half the size of the Earth, and is only around 11 per cent of the mass, dramatically reducing its gravitational pull.

10 A vast canyon opened up as the crust stretched

One of the most striking features on the surface of Mars is Valles Marineris, named after the Mariner 9 orbiter that discovered it. The vast canyon stretches across the equator and is over 4,000 kilometres (2,485 miles) in length, seven kilometres (four miles) deep and is thought to have been formed when the planet cracked as it cooled.

NASA's Gaylon McSmith, current project manager for Mars Odyssey Explorer, which revealed water ice beneath the Martian poles

11

The ground is filled with water ice

One of the major questions surrounding Mars was what had happened to its water. Today, it cannot exist as a liquid on the surface, and instantly sublimes into vapour, before escaping the atmosphere into space. However, in the past the planet was covered with lakes, streams and possibly even oceans.

Between 2001 and 2002, the Mars Odyssey Explorer looked for hydrogen beneath the surface of Mars, evidence that there might be trapped water. The map it returned revealed that beneath the dry carbon dioxide ice at the poles there is a huge quantity of water ice. The radar sounder onboard ESA's Mars Express orbiter later revealed that there is enough potential water trapped under the Martian poles to cover the entire planet in an ocean 11 metres (36 feet) deep.

12

The core might still be molten

The lack of magnetic field around Mars indicates the core might have solidified, but the Mars Reconnaissance Orbiter revealed evidence of plate tectonics, with features some scientists say are reminiscent of the San Andreas fault in California, where two plates are moving horizontally past each other.

> "In the past the planet was covered with lakes, streams and even oceans"

13

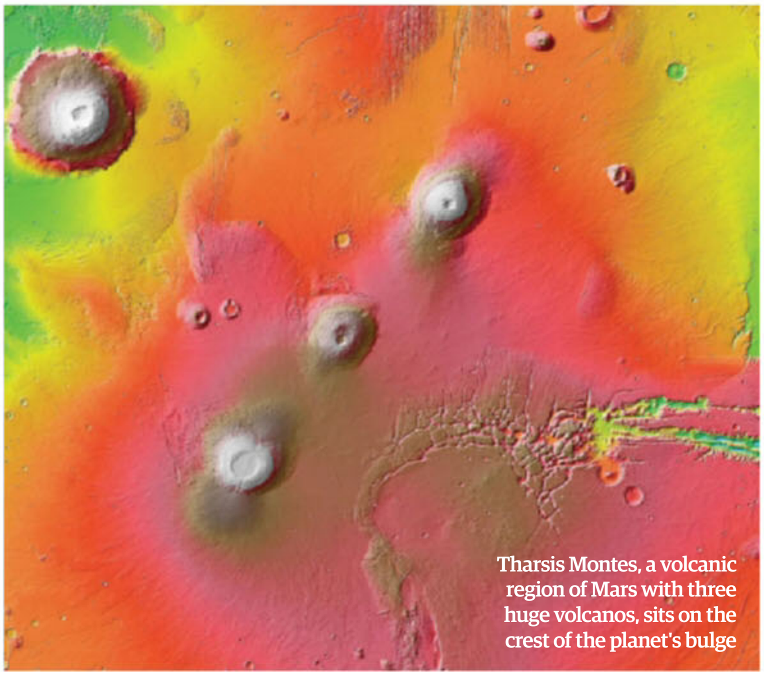
Mars has seasons

Seasons represent changes in day length and climate throughout the year, and are dependent upon a planet's distance to the Sun. If a planet is spinning straight up on its axis the equator always gets the same amount of sunshine every day, but if the planet is tilted the daylight hours vary slightly throughout the year. Earth is tilted on its axis by a little over 23 degrees, and Mars by 25 degrees, and both experience seasonal variations.

Mars differs from the Earth in that it has a more elliptical orbit and at certain times of the year is much closer to the Sun. As a result, spring and summer are longer in the northern hemisphere than they are in the southern, because when the north is tilted towards the Sun on the axis the entire planet is farther away in its orbit and so travels slower.

While the northern hemisphere enjoys a long summer, the winters at the southern hemisphere are harsh, and for much of the time the south pole is in complete darkness. The temperature drops so low that carbon dioxide solidifies out of the air, forming a permanent cap of dry ice over the region. NASA's first ever landers to reach the surface of the Red Planet, Viking 1 and Viking 2 showed that atmospheric pressure drops by as much as 25 per cent as the gas freezes in the winter.

At Mars's permanent south pole, winter temperatures plummet as low as -153C (-243F)

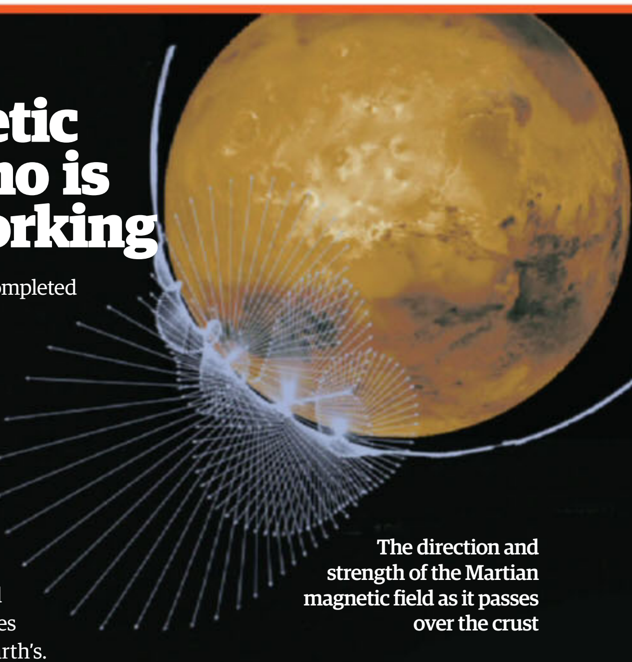


Tharsis Montes, a volcanic region of Mars with three huge volcanos, sits on the crest of the planet's bulge

14 It has shifted on its axis

NASA's Mars Global Surveyor completed a full map of the surface of Mars in 2001, but something didn't quite match up. The positions of the shorelines where regions of water might have been weren't level. A team at the University of California, Berkeley showed that the shoreline movement might be down to the change in the spin axis of Mars. The spin axis of Mars is not fixed like Earth's, but has changed over its lifetime, and crust has moved relative to the axis over a distance of around 3,000 kilometres (1,864 miles) along the surface in the last 2 to 3 billion years. As planets spin the motion causes them to bulge in the centre, and the group calculated that deformation in the crust would have changed the water level to match the patterns seen in the shorelines. It is even thought that floodwater might have contributed to the tilting of the planet, tipping the planet by 50 degrees, and then tilting it back again by 20 degrees as it dried out.

15 Its magnetic dynamo is not working



The direction and strength of the Martian magnetic field as it passes over the crust

When Mariner 4 completed its flyby in 1965, it became apparent that something was wrong with Mars's magnetic field, and by 1989, a low-orbiting probe, Phobos 2, sent to Mars by the Soviet Union had revealed that it is 3,000 times weaker than the Earth's.

Earth has a molten iron outer core, which circulates inside the planet, powering an internal magnetic dynamo. It acts like a giant bar magnet, generating magnetic field lines that spring out from the poles and encircle the Earth, deflecting solar winds and helping to protect the atmosphere. On Mars, these field lines are missing and, rather than circling the planet, weak magnetic fields are fixed in specific locations, mainly in the southern hemisphere. Earth's magnetic field periodically changes direction, and its magnetic history is written in to the rocks, with alternating bands of magnetic material deposited in opposite directions. NASA's Mars Global Surveyor found similar striped magnetic field lines in the ground of the southern highlands, indicating that at some point Mars had a functioning dynamo. These stripes are absent from the northern hemisphere, which formed much later in the history of the planet, suggesting the dynamo stopped functioning a few hundred million years after Mars formed.

16 Mars is still losing its atmosphere

The atmospheric pressure on Mars ranges from around five to ten millibars (compared to 1,000 millibars here on Earth). The Red Planet is around 50 per cent smaller in diameter than Earth, and its lower gravity would have allowed the outer layers of the atmosphere to escape early in its life, particularly during energetic asteroid collisions. As the atmosphere started to thin, it would have provided less resistance to incoming asteroids, which would have resulted in even more collisions, beginning a vicious cycle of atmospheric loss. Without a functioning magnetic field, the Red Planet is also vulnerable to the effects of solar winds.

The Mars Express carries an imager capable of detecting the effects of solar winds, and showed that today, charged particles enter the Martian atmosphere, ionising the gases and allowing them to escape into space. NASA's Mars Atmosphere and Volatile Evolution (MAVEN) orbiter arrived on 21 September 2014, followed a few days later by India's Mars Orbiter Mission (Mangalyaan), and the two teams are collaborating to discover more about how Mars lost its protective sphere of gas.

Mission Profile

Mars Global Surveyor

Launched: 7 November 1996
Arrived at Mars: 12 September 1997
Mission goal: To characterise the surface features and geological processes on Mars
Current status: Contact ceased November 2006

Comet Siding Spring gave Mars a spectacular show as it passed nearby in October

17 It just had a near miss with a comet

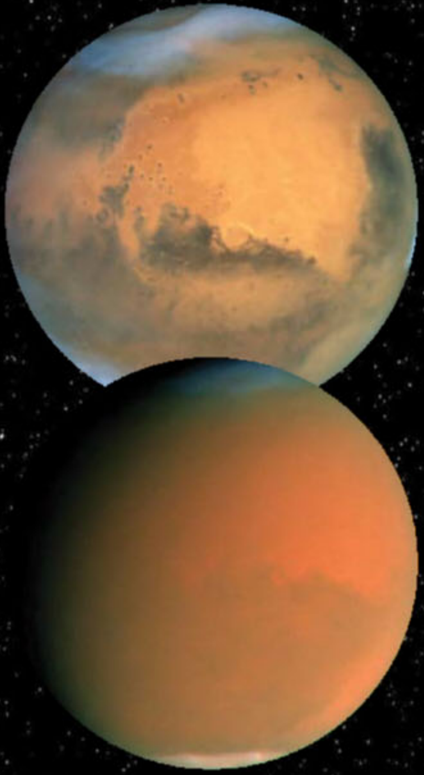
The comet Siding Spring was discovered in January 2013 and in October 2014, it passed within 139,500 kilometres (86,680 miles) of the surface of Mars, just under a third of the distance from the Earth to the Moon. At the time there were two active rovers on the surface of the planet (Opportunity and Curiosity) and five active orbiters. All pointed their cameras in its direction.

The dust from the tail of the comet could easily have damaged the orbiting spacecraft, so the active orbiters, Mars Express, Mars Orbiter Mission, Mars Odyssey, Mars Reconnaissance Explorer and MAVEN waited on the opposite side of the planet. The comet passed without incident, and four orbiters managed to take pictures as it went.

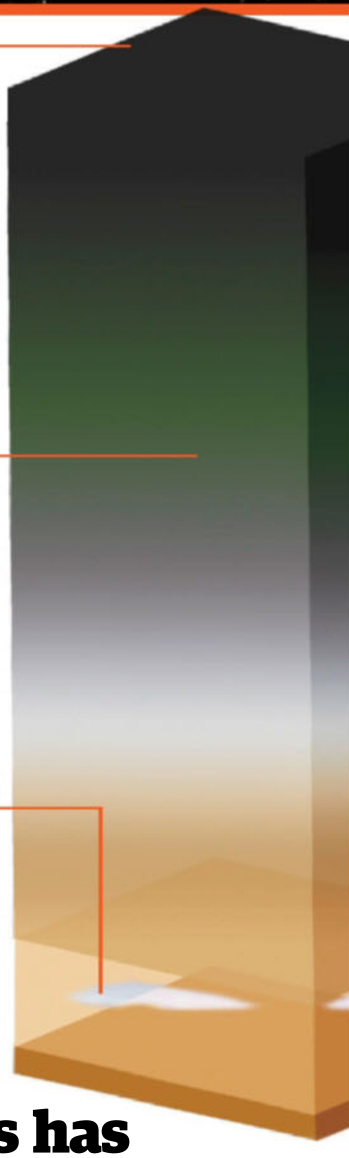
18 Dust storms can shroud the entire planet

The dust that covers the surface of Mars is as fine as smoke and can float even in the painfully thin atmosphere. The biggest dust storm ever recorded on the Red Planet was seen by Mariner 9 when it arrived in 1971 and, since 1997, the Mars Global Surveyor has been in a polar orbit around Mars, tracking the weather.

As the ground heats up in the morning each spring, dust devils begin to form. Energy from the Sun is absorbed by the dust and rocks and in turn starts to heat the gases. They then rise up through the cold air, creating a spinning vortex. NASA says that the atmosphere is so thin that you wouldn't feel much wind on Mars, but that the fine dust whips through the air, building up static and releasing electrical arcs. As the day cools the storms subside, but the tiny dust particles can fly tens of kilometres into the air. In the low gravity, it takes a long time for them to fall back down to the surface again, with some remaining airborne for months.



The surface of Mars prior to (top) and during (above) the 2001 global dust storm as captured by Hubble



Upper
As you move up through the Martian atmosphere the pressure drops rapidly and the temperature rises. At altitudes of above around 200km (124mi), the gases begin to tail off into space, with no clear boundary between the atmosphere and the vacuum.

Middle
The combined effect of the spin of the planet, and the heating and cooling of the gases and dust in the atmosphere creates jetstreams between the lower and upper layers of the atmosphere. A similar effect can be seen on Earth.

Lower
In the lower atmosphere, dust particles absorb heat from the Sun, warming the air to around -63°C (-82°F). Clouds of water ice and carbon dioxide form in this layer, and dust storms regularly fill the air.

19 Mars has carbon dioxide weather

The atmosphere on Mars was first analysed during the Mariner 4 flyby, and has been tested by several orbiters since. The first accurate measurements of its composition were made by the Viking landers, revealing that the thin air is 95.32 per cent carbon dioxide, 2.7 per cent nitrogen, and 1.6 per cent argon. Just 0.13 per cent of the atmosphere is oxygen, and 0.03 per cent is water vapour. In contrast, the atmosphere on Earth is 78 per cent nitrogen, 21 per cent oxygen, and just 0.04 per cent carbon dioxide.

The European Space Agency launched its Mars Express orbiter in 2003, and has been monitoring the atmosphere ever since. It has observed carbon dioxide clouds forming around 80 kilometres (50 miles) in the air above the equator, and watched as it freezes down to cap the poles each winter. The orbiter also detected traces of methane gas alongside water vapour, sparking scientific interest in the potential for volcanic activity, or even life, beneath the surface.

Mission Profile

Mars Express

Launched: 2 June 2003
Arrived at Mars: 25 December 2003
Weight: 113kg (249lb)
Mission goal: To image the entire surface of Mars at super-high resolution
Current status: Active

The surface of Mars has seen more than its fair share of violent outbursts in the last billion years

21

Gas jets spray from the south pole every spring

The Mars Reconnaissance Orbiter, launched in 2001, revealed that as the temperature rises in the spring the dry ice covering the south pole begins to sublime. Pockets of heated gas explode outwards as jets, throwing dust into the air and creating dark spider-shaped marks on the surface of the planet.

20 There has been recent volcanic activity on Mars

The history of Mars is mapped out in the rocks that cover its surface and, using data gathered from orbiters and landers, scientists are beginning to piece together the planet's past. Over time, conditions on the surface have changed dramatically.

The Mariner 4 spacecraft observed some of the planet's oldest regions, craters made in the southern hemisphere during the heavy bombardment that battered the rocky planets around 4 billion years ago. Although this part of the surface has remained largely unchanged, the rest of the planet has since been remodelled. The northern hemisphere is much less cratered and has been covered with smooth lava plains, and the tops of the shield volcanoes at the equator indicate that they were recently active. Lava flows from the volcanoes repeatedly covered up impact craters, and by looking at the calderas at the top of the mountains it is possible to estimate when they last erupted. ESA's Mars Express has been examining the volcanoes, and scientists estimate that volcanic activity continued until 100 to 200 million years ago, with evidence of lava flows within the last few million years. It may be that the volcanoes are dormant, not extinct.

> "Shield volcanoes at the equator were recently active"

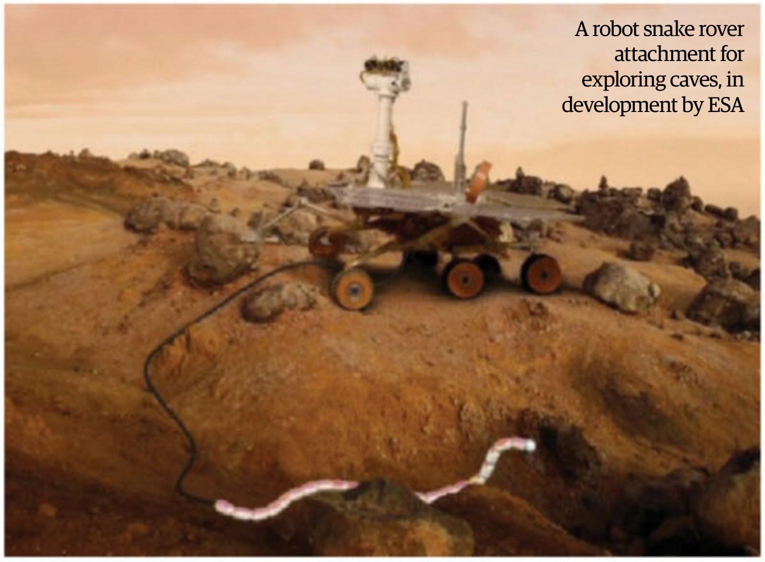
22 Travelling to Mars is extremely challenging

It will be far trickier to safely send astronauts to Mars than it was to send them to the Moon

If there is one thing that we have learnt about Mars over the last 50 years of space exploration, it is that travelling to the Red Planet is incredibly difficult. The first flyby in 1965 was the seventh attempt at reaching the planet and, since then, several more orbiters and landers have been lost. In the Nineties, four of NASA's six missions to the Red Planet failed. In 2003, the European Space Agency lost the Beagle 2 Lander launched alongside the successful Mars Express. And Russia and China's joint effort Phobos-Grunt/Yinghuo-1 was trapped in orbit around Earth in 2011.

Those that did reach the Red Planet had problems of their own. Although the Phoenix lander outlasted its three-month mission, its solar panels were eventually destroyed by the weight of many tens of kilograms of dry ice during the winter and, after six years on the surface, a wheel on NASA's Spirit rover stopped working, causing it to become irrevocably trapped in the Martian sands in 2009. More recently, NASA's Curiosity rover experienced unexpectedly quick damage to its aluminium wheels, forcing scientists to drive it in reverse.

But despite all these problems, we have learnt a huge amount about Mars and the combined information from both the successes and failures is being assembled and used to inform current and future missions. Using the information we have acquired, NASA intends to take humans to Mars in the 2030s.



A robot snake rover attachment for exploring caves, in development by ESA

23 There are caves on Mars

In 2007, the infrared cameras of the Mars Odyssey Orbiter spotted a set of caves on the surface of Mars, dubbed the Seven Sisters. They are located on the side of one of the shield volcanoes, Arsia Mons, and are visible as 'skylights', extending tens of metres downwards into lava tubes or sinkholes. Caves on Mars could provide easier access to buried layers of ancient rock without the need for heavy-duty drilling. These sheltered areas might be a good place to search for evidence of past life on the planet.

24 Sunsets are purple on Mars

The Viking 1 lander returned the first images of the Martian sunset in the Seventies. The fine red dust particles tint the sky a pinkish colour in the evening, but as the Sun starts to dip below the horizon, blue light is scattered, creating a purplish hue.

25 Mars has ozone layers

ESA's Mars Express orbiter has been circling the planet since 2003, and is equipped with a UV spectrometer called SPICAM. It's shown that Mars has an ozone layer at an altitude of 30 kilometres (19 miles), another in the northern spring/summer at between 30 to 60 kilometres (19 to 37 miles), and a third above the south pole in winter at around 40 to 60 kilometres (25 to 37 miles).

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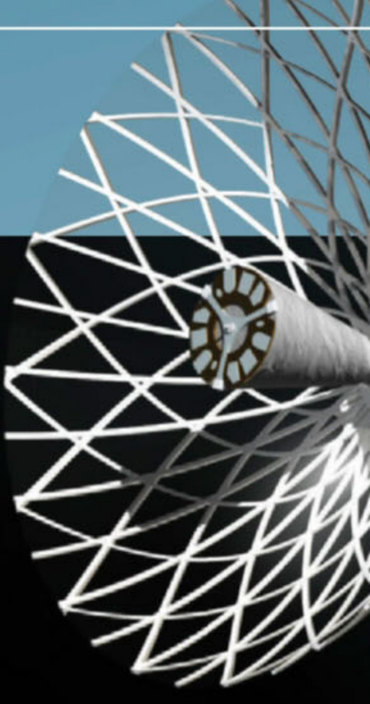


Satellite repair droids

What to do when an outer space satellite breaks down? Send in the robots!

Droids could soon be placed on satellites in geostationary orbit (GEO) around the Earth to make the job of repairing and maintaining them much easier and cheaper.

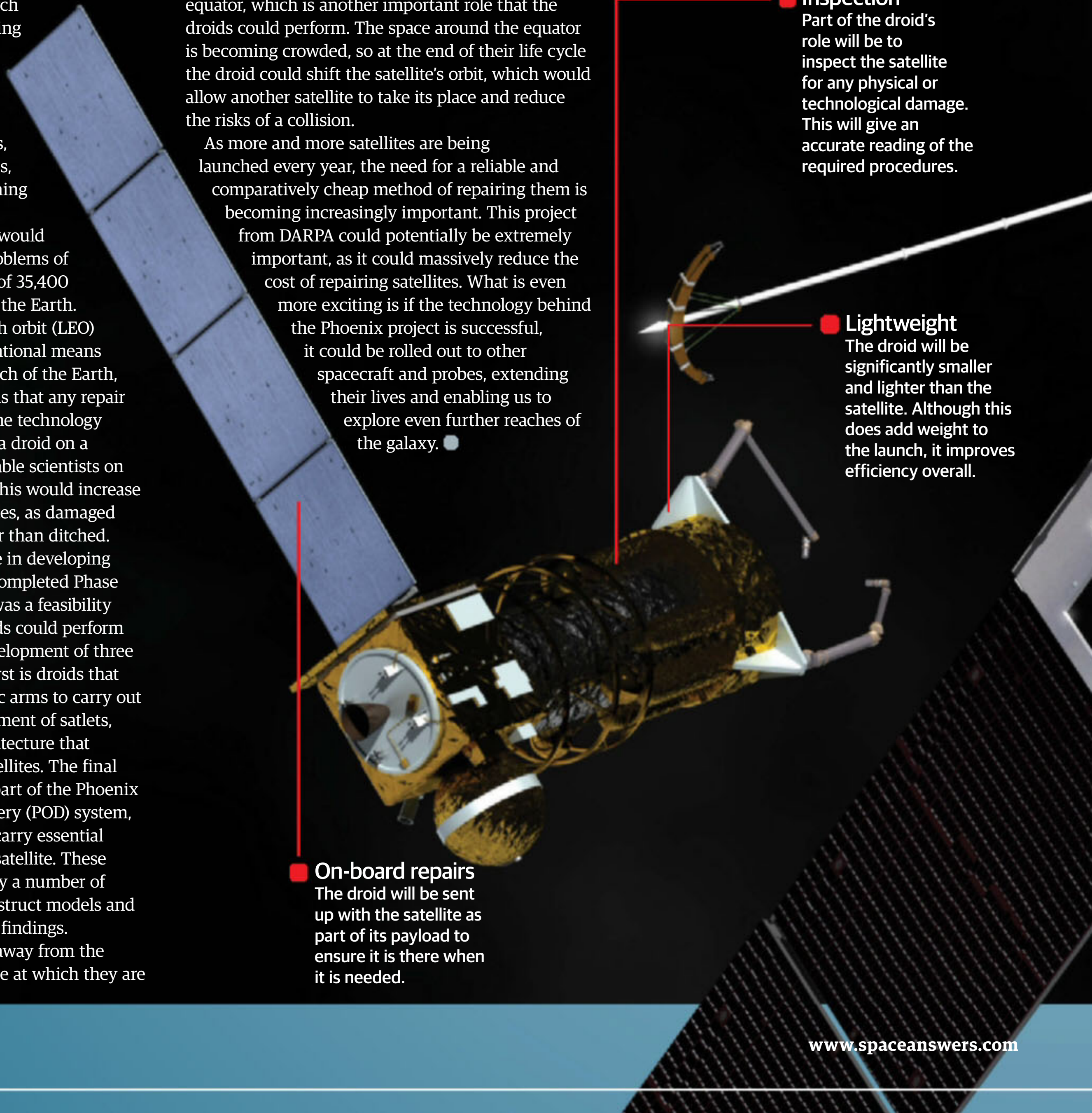
The Defense Advanced Research Projects Agency (DARPA) is looking at the possibility of installing robots on satellites before they are launched into orbit. Once on board, the droids would be responsible for a number of tasks, including inspecting the satellites, fixing any problems and performing orbit adjustments.

This project, named Phoenix, would slash the cost of dealing with problems of satellites that orbit at a distance of 35,400 kilometres (22,000 miles) above the Earth. Satellites operating in a low Earth orbit (LEO) are able to be repaired by conventional means because they are within easy reach of the Earth, but the height of the GEOs means that any repair missions are unreachable with the technology currently available. Establishing a droid on a satellite before launch would enable scientists on Earth to affect a remote repair. This would increase the life expectancy of the satellites, as damaged satellites could be repaired rather than ditched.

DARPA is asking for assistance in developing the technology, having already completed Phase 1 of the Phoenix project, which was a feasibility study into what actions the droids could perform in space. Phase 2 will be the development of three main areas of technology. The first is droids that can repair satellites, using robotic arms to carry out tasks. The second is the development of satlets, which are modular satellite architecture that can carry out similar roles to satellites. The final technology being developed as part of the Phoenix project is a Payload Orbital Delivery (POD) system, which is a mechanism that can carry essential items into space along with the satellite. These three areas are being looked at by a number of private companies, who will construct models and report back to DARPA with their findings.

The GEOs need to be that far away from the Earth because that is the distance at which they are able to be in geosynchronous orbit with the Earth. This is where the satellite orbits at the same time as the Earth so it is always over the same point. There are currently over 900 satellites in GEO over the equator, which is another important role that the droids could perform. The space around the equator is becoming crowded, so at the end of their life cycle the droid could shift the satellite's orbit, which would allow another satellite to take its place and reduce the risks of a collision.

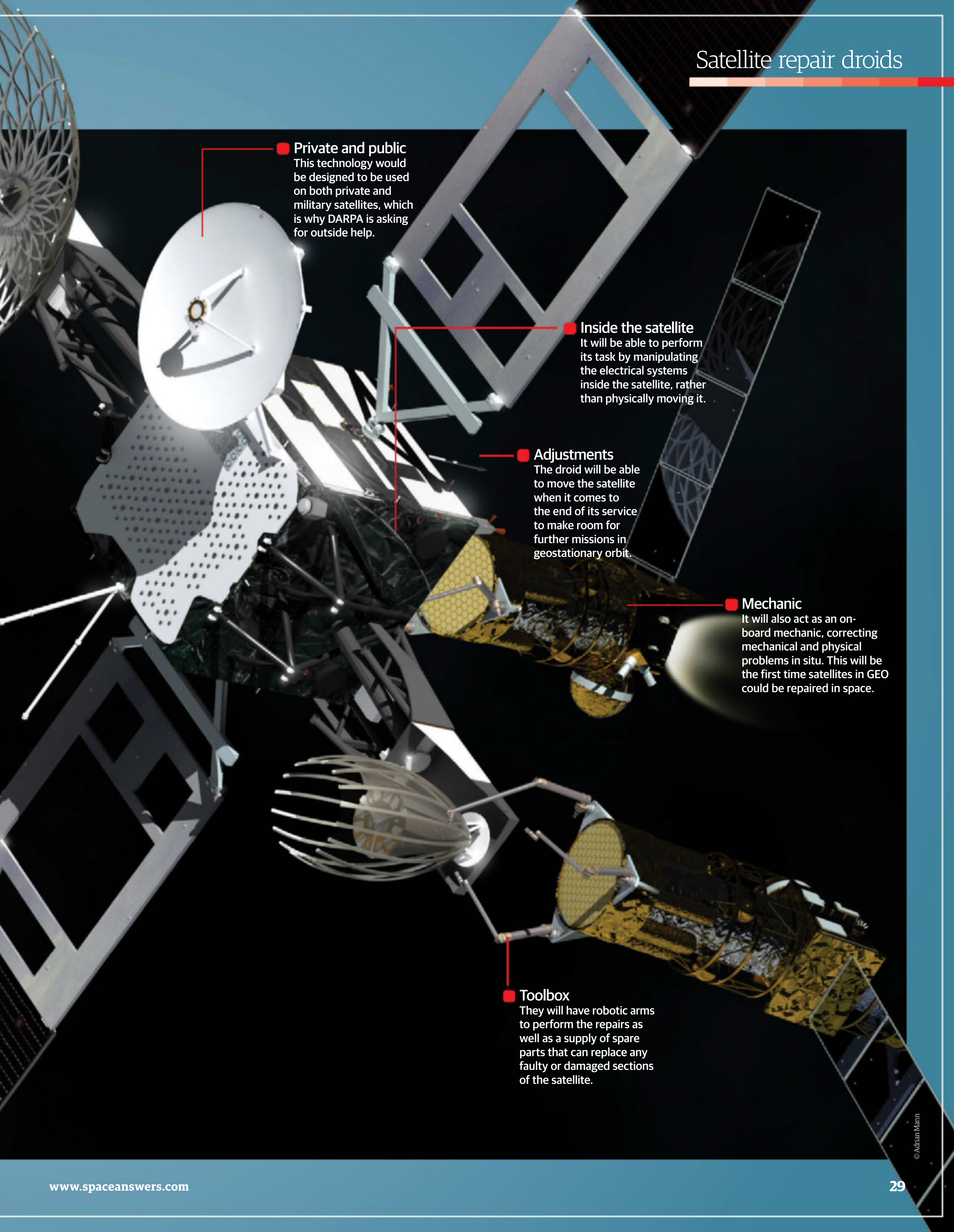
As more and more satellites are being launched every year, the need for a reliable and comparatively cheap method of repairing them is becoming increasingly important. This project from DARPA could potentially be extremely important, as it could massively reduce the cost of repairing satellites. What is even more exciting is if the technology behind the Phoenix project is successful, it could be rolled out to other spacecraft and probes, extending their lives and enabling us to explore even further reaches of the galaxy.



Inspection
Part of the droid's role will be to inspect the satellite for any physical or technological damage. This will give an accurate reading of the required procedures.

Lightweight
The droid will be significantly smaller and lighter than the satellite. Although this does add weight to the launch, it improves efficiency overall.

On-board repairs
The droid will be sent up with the satellite as part of its payload to ensure it is there when it is needed.



Private and public
This technology would be designed to be used on both private and military satellites, which is why DARPA is asking for outside help.

Inside the satellite
It will be able to perform its task by manipulating the electrical systems inside the satellite, rather than physically moving it.

Adjustments
The droid will be able to move the satellite when it comes to the end of its service to make room for further missions in geostationary orbit.

Mechanic
It will also act as an on-board mechanic, correcting mechanical and physical problems in situ. This will be the first time satellites in GEO could be repaired in space.

Toolbox
They will have robotic arms to perform the repairs as well as a supply of spare parts that can replace any faulty or damaged sections of the satellite.

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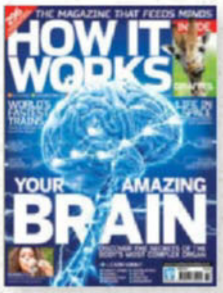

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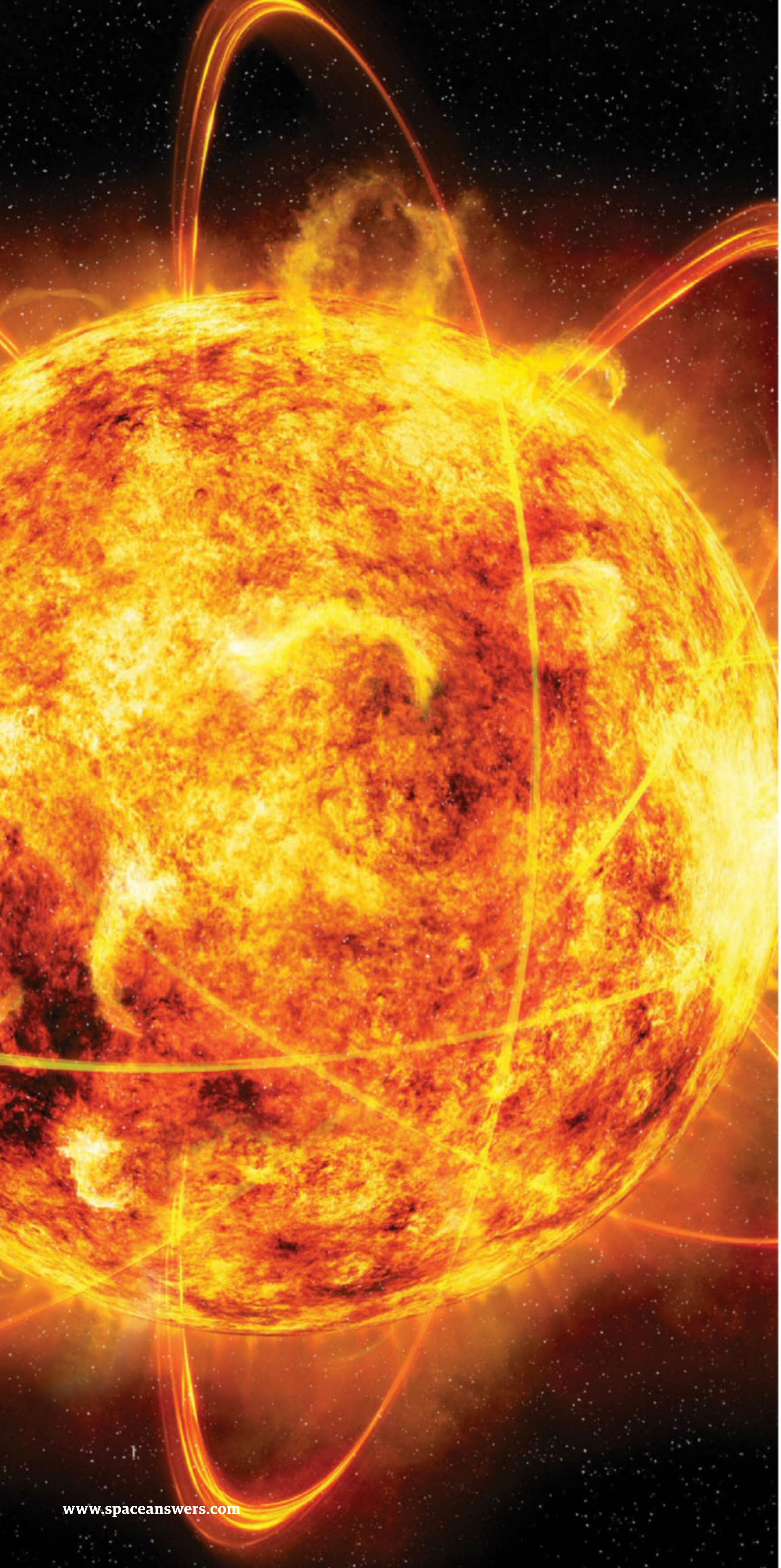
FUSION POWER SUN

Our local star pumps out vast amounts of heat and light, which supports all life on Earth. But where does it come from, and just what happens to it on its journey through the Sun?

Written by Giles Sparrow



Fusion power Sun

The Sun is a huge ball of blazing gas, with a visible surface roughly 1.4 million kilometres (870,000 miles) across. In a single second it pumps out energy equivalent to what could be generated by 2 billion large Earth power stations in a year, making use of a process that scientists have only been able to harness for a fraction of a second in Earth-based laboratories: nuclear fusion.

Fusion is the process of joining together the atomic nuclei of light elements to build the nuclei of heavier ones. All atoms consist of a nucleus (a tiny, positively charged core that accounts for the vast majority of their mass) surrounded by a cloud of orbiting electrons (lightweight, negatively charged particles). In comparison to the entire atom, the nucleus is about the size of a pea inside an electron cloud the size of a football stadium. In the extreme conditions of the Sun's interior, atoms break apart into their component electron and nuclei, allowing matter to reach extreme densities (about 150 times the density of water). Heated to temperatures of around 15 million degrees Celsius (27 million degrees Fahrenheit) in the core of the Sun, atomic nuclei are slammed together at high speed - and the changes they go through in order to remain stable release the energy that allows the Sun to shine.

A century ago, the source of the Sun's power was one of the biggest questions in astronomy. Geological and fossil discoveries had shown that the Earth was hundreds of millions, if not billions, of years old. But popular models of the Sun's power source, such as the idea that it generated energy by slow gravitational contraction, suggested that it could only sustain Sun-like levels of energy for a few tens of millions of years.

Clues to a solution came from a number of different directions. Spectroscopy (the analysis of light from the Sun and other objects to identify the chemical fingerprints of their constituents) had revealed that our star and most others are dominated by the two lightest and most abundant elements in the universe - hydrogen and helium. Most astronomers agreed that the Sun and planets had formed by collapsing out of a cloud of interstellar gas (mostly hydrogen) and dust similar to some of the nebulae they saw through their telescopes, and it seemed clear that stars had to become dense and hot in the first place in order to start shining. At around the same time, physicists and chemists were discovering the secrets of atomic structure for the first time, and precise measurements of atomic masses showed that a single atom of helium contained almost four times the mass of four individual hydrogen atoms.

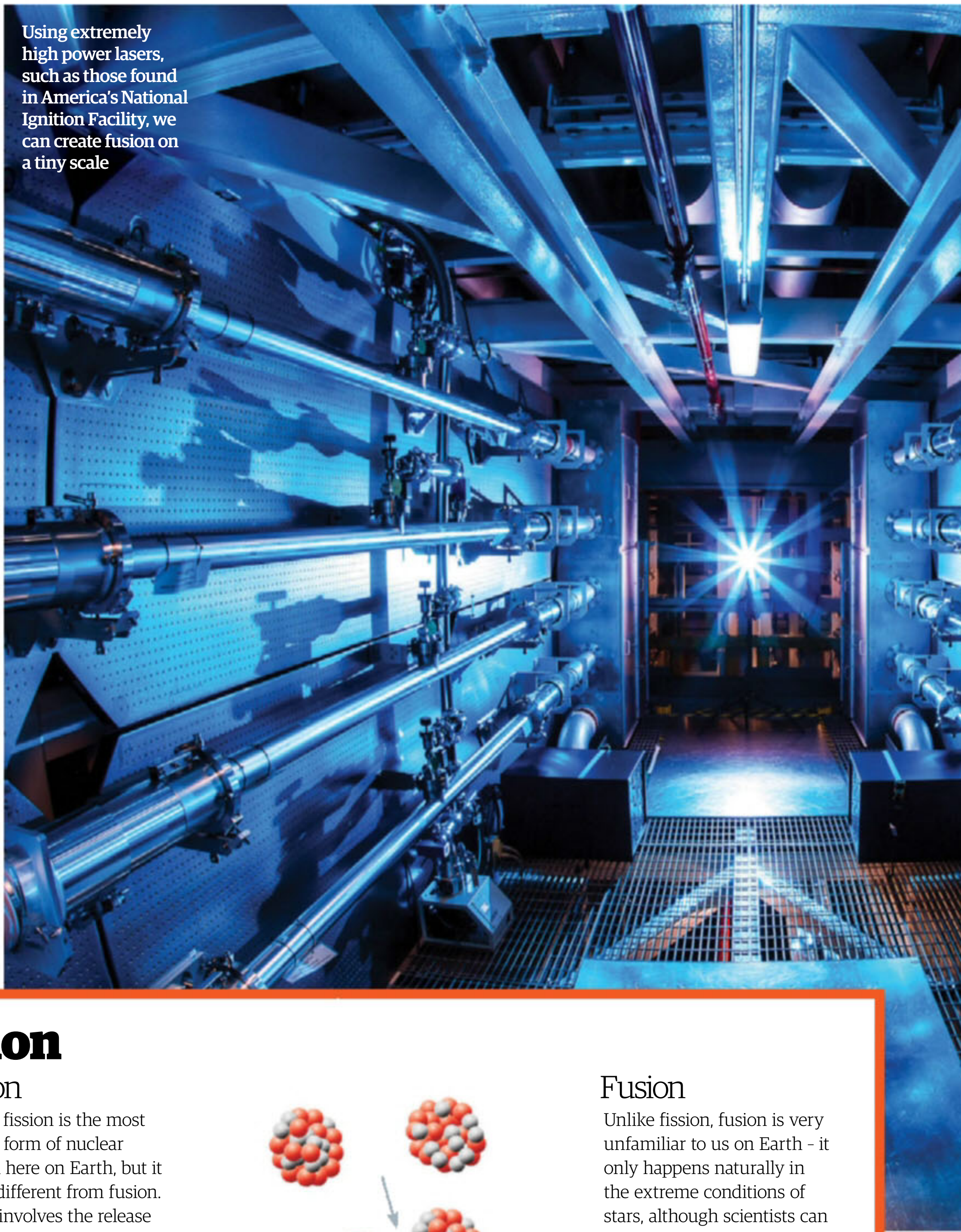
Then, in 1920, British astrophysicist Arthur Stanley Eddington put forward an ingenious idea - what if the Sun generated its energy by combining lightweight hydrogen nuclei to make helium? If four hydrogen nuclei fuse to form a single helium nucleus, there will be a small but significant amount of mass (roughly 0.7 per cent) 'left over', and Eddington suggested this might be converted directly into a relatively large amount of energy according to Einstein's famous equation E=mc2.

Today we know this is exactly what happens at the centre of stars like the Sun - 620 million tons of hydrogen nuclei are fused into helium every second. However, it took decades, and many further discoveries about the nature of the nucleus, before astrophysicists could describe what happens in detail.

Nuclear fusion in the Sun takes place mostly through a process known as the proton-proton (p-p) chain. Today we know that atomic nuclei consist of two distinct particles – positively charged protons and uncharged neutrons – with identical masses. The number of protons dictates the number of electrons required to balance them, and therefore the atom's chemical properties and which element it forms. Neutrons, meanwhile, provide additional mass and stability, forming variant atoms of the same element with the same chemistry but different mass. These are known as isotopes.

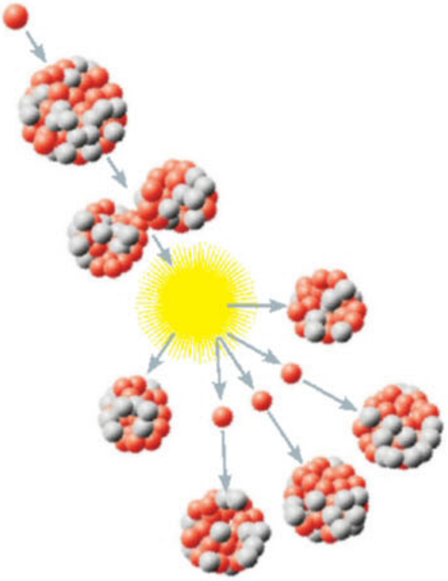
Hydrogen usually consists of atoms with just a single lone proton orbited by a single electron. In the extreme conditions of a stellar interior, however, these atoms are ionised, with their electrons stripped away to expose the bare nucleus. A helium nucleus, in contrast, contains two protons and two stabilising neutrons – so where do the neutrons come from? It seems that during the fusion process, protons are able to spontaneously transform into neutrons through a process known as beta-plus decay. The proton effectively 'sheds' its positive charge by emitting a positron (the positively charged equivalent of an electron) and an almost-massless particle known as a neutrino. P-p chain fusion actually involves several distinct pathways and each of its steps releases energy, while any positrons that may have been liberated along the way soon collide with electrons and disappear in another burst of energy known as annihilation.

At relatively large scales (those of whole atoms), we might expect repulsion due to the familiar electromagnetic force to push positively charged protons away from each other. However, given enough temperature, speed and pressure, the protons



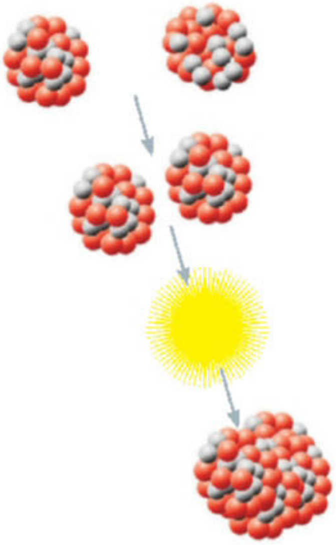
Using extremely high power lasers, such as those found in America's National Ignition Facility, we can create fusion on a tiny scale

Fission versus Fusion



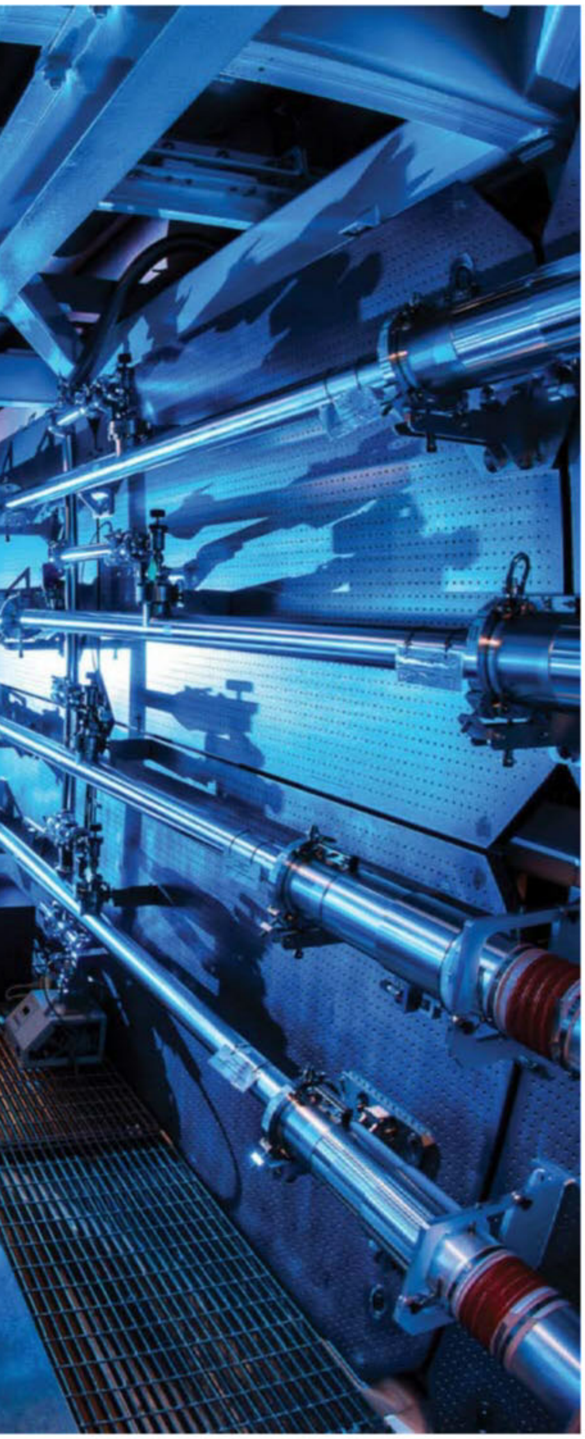
Fission

Nuclear fission is the most familiar form of nuclear reaction here on Earth, but it is very different from fusion. Fission involves the release of energy from the splitting apart of a heavy atomic nucleus whose configuration of protons and neutrons have left it unstable or 'radioactive' – it produces one or more lighter nuclei along with other subatomic particles or excess energy. Fission happens regularly in nature, but can also be triggered artificially, which is the principle behind nuclear power stations and, unfortunately, atomic bombs as well.



Fusion

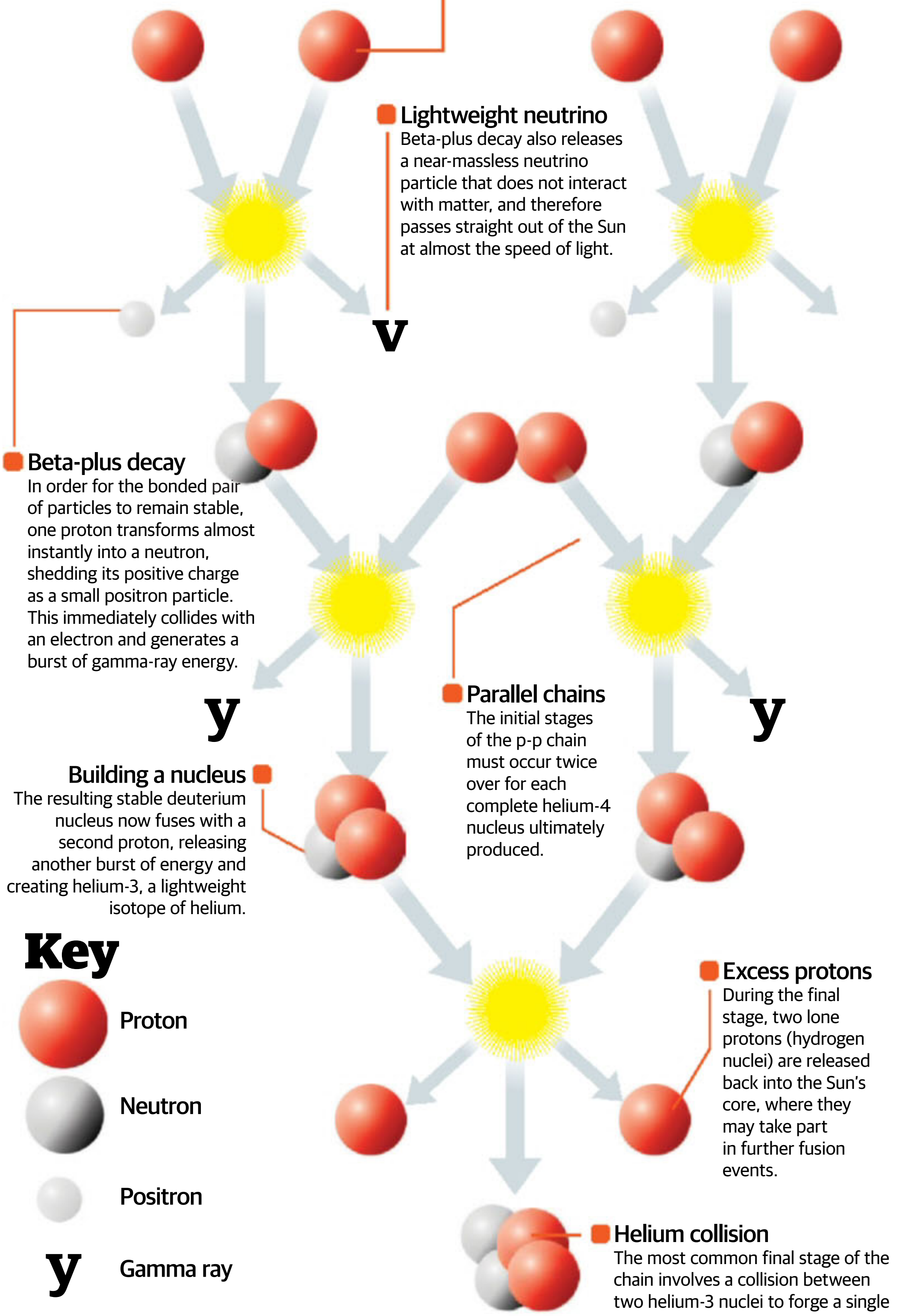
Unlike fission, fusion is very unfamiliar to us on Earth – it only happens naturally in the extreme conditions of stars, although scientists can replicate it in experiments. Fusion is the forging together of lighter atomic nuclei to make heavier ones and release energy – in the Sun, this mostly involves fusing hydrogen to make helium but in other stars it's possible to fuse elements up to and including iron (elements beyond this absorb energy in the process). Harnessing nuclear fusion remains a dream at the moment, but it offers a potentially limitless source of clean energy.



> “Life on Earth could not have come into being without nuclear fusion in the Sun: we could not survive without it”

Proton-proton chain fusion

P-p chain fusion actually involves several distinct pathways, but the early steps always involve the fusing of two protons to form a highly unstable isotope called helium-2.



Colliding protons
Stripped of their electrons in the heart of the Sun, exposed hydrogen nuclei are simply individual positively charged protons. At intense temperatures and pressures, they are forced together, overcoming forces of electromagnetic repulsion.

Lightweight neutrino
Beta-plus decay also releases a near-massless neutrino particle that does not interact with matter, and therefore passes straight out of the Sun at almost the speed of light.

Beta-plus decay
In order for the bonded pair of particles to remain stable, one proton transforms almost instantly into a neutron, shedding its positive charge as a small positron particle. This immediately collides with an electron and generates a burst of gamma-ray energy.

Parallel chains
The initial stages of the p-p chain must occur twice over for each complete helium-4 nucleus ultimately produced.

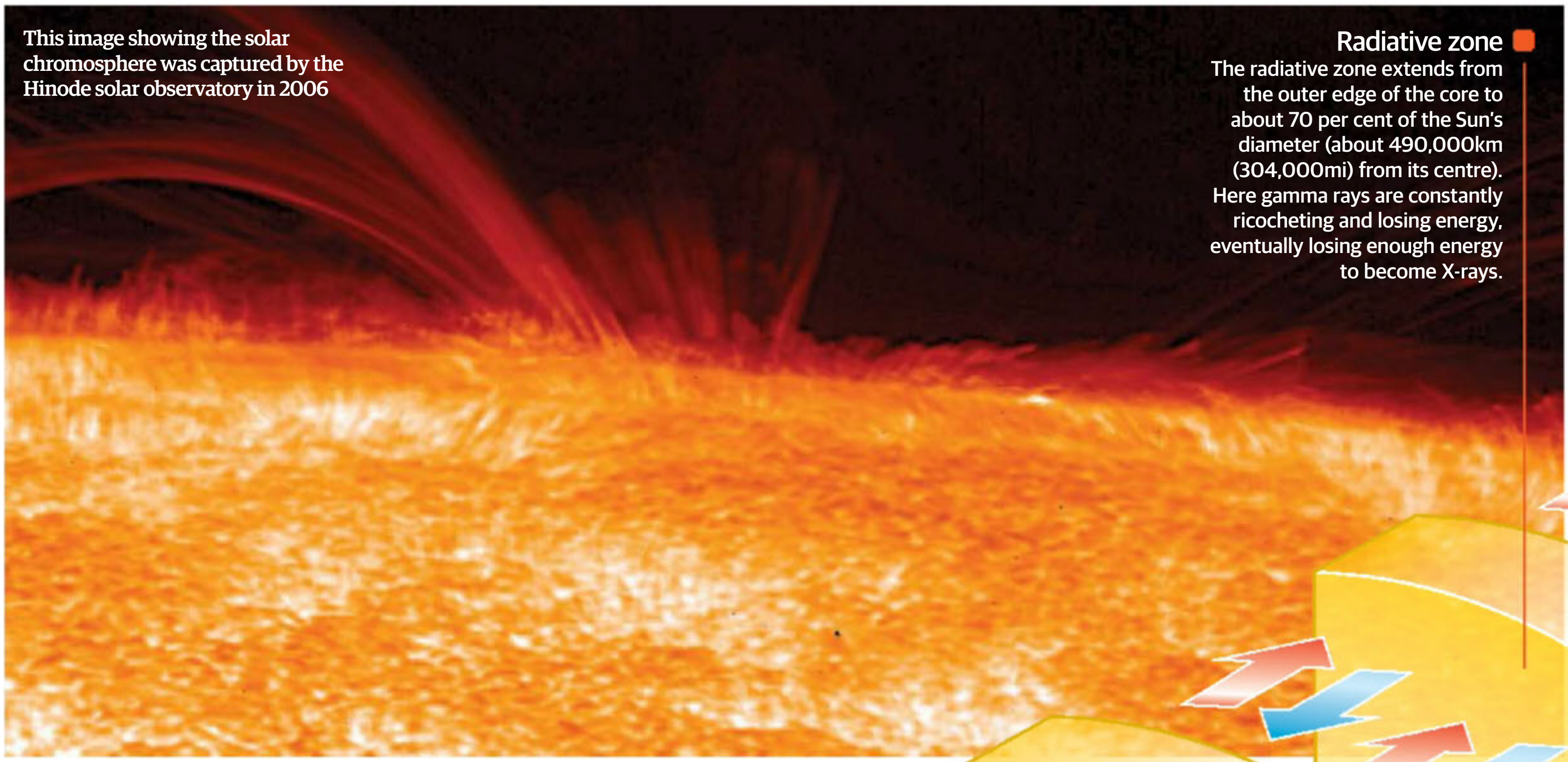
Building a nucleus
The resulting stable deuterium nucleus now fuses with a second proton, releasing another burst of energy and creating helium-3, a lightweight isotope of helium.

Excess protons
During the final stage, two lone protons (hydrogen nuclei) are released back into the Sun’s core, where they may take part in further fusion events.

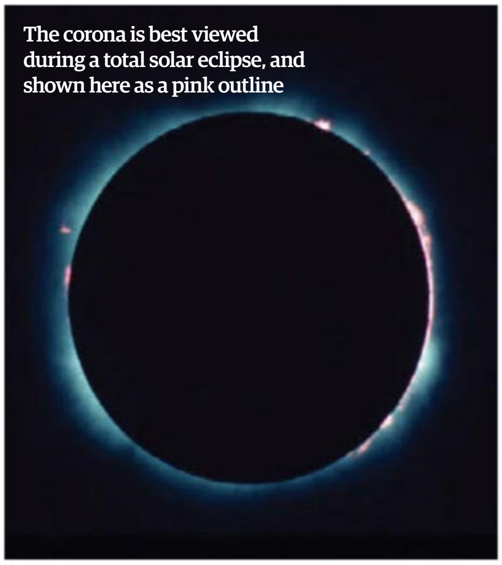
Helium collision
The most common final stage of the chain involves a collision between two helium-3 nuclei to forge a single nucleus of helium-4 and release another burst of energy.

Key

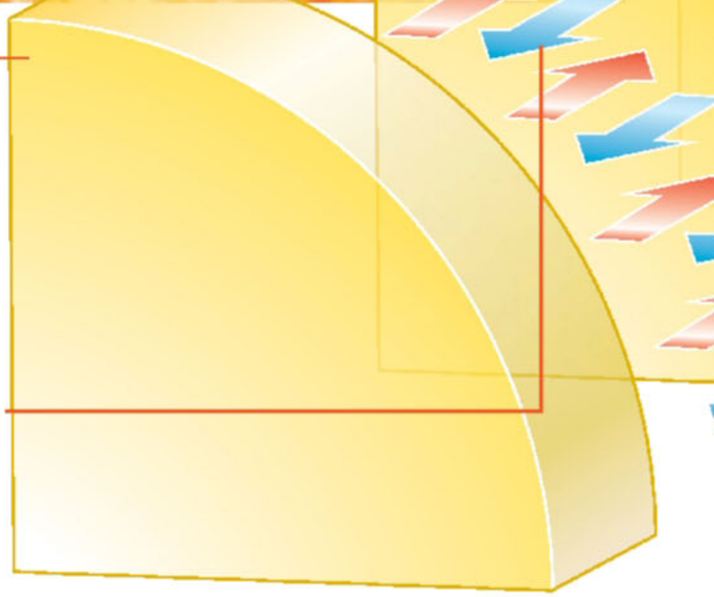
🔴	Proton
⚫	Neutron
⚪	Positron
y	Gamma ray
v	Neutrino



This image showing the solar chromosphere was captured by the Hinode solar observatory in 2006



The corona is best viewed during a total solar eclipse, and shown here as a pink outline



Radiative zone

The radiative zone extends from the outer edge of the core to about 70 per cent of the Sun's diameter (about 490,000km (304,000mi) from its centre). Here gamma rays are constantly ricocheting and losing energy, eventually losing enough energy to become X-rays.

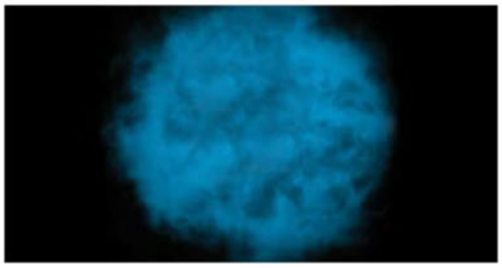
Inner core

The Sun's core, where fusion can be sustained, takes up about 20 per cent of its diameter (roughly 22 times the width of Earth). High temperatures and pressures allow hydrogen nuclei (protons) to fuse together, building into helium nuclei and releasing energy in the process.

Hydrostatic equilibrium

At every point within the Sun's overall structure, the outward pressure from radiation and the inward pull of gravity must be precisely balanced to prevent material being dragged inwards or blown away.

How did our Sun form?

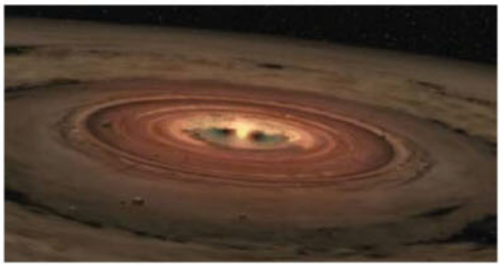


1. Origins of a star

Our Sun and its planets were born when a hydrogen-rich cloud of interstellar gas and dust began to slowly collapse around 5 billion years ago.

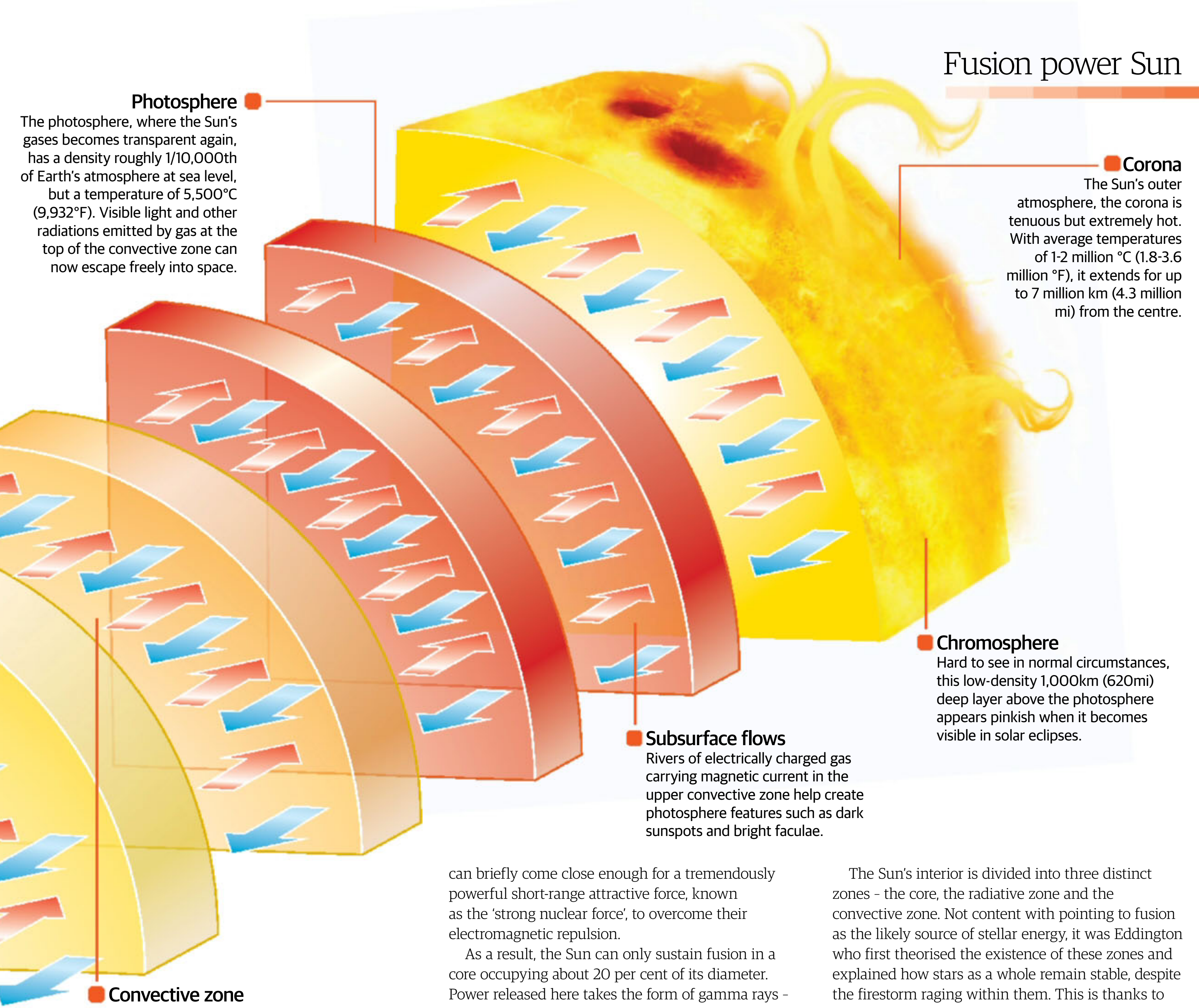
2. Flattening out

As the cloud grew denser it span faster. Collisions within the cloud tended to even out its rotation, resulting in a flattened disc with a large central bulge.



3. Condensing Sun

As the central region of the 'protostellar nebula' grew more massive, its gravity began to pull in more material, gradually condensing and heating up.



Photosphere
The photosphere, where the Sun's gases becomes transparent again, has a density roughly 1/10,000th of Earth's atmosphere at sea level, but a temperature of 5,500°C (9,932°F). Visible light and other radiations emitted by gas at the top of the convective zone can now escape freely into space.

Corona
The Sun's outer atmosphere, the corona is tenuous but extremely hot. With average temperatures of 1-2 million °C (1.8-3.6 million °F), it extends for up to 7 million km (4.3 million mi) from the centre.

Chromosphere
Hard to see in normal circumstances, this low-density 1,000km (620mi) deep layer above the photosphere appears pinkish when it becomes visible in solar eclipses.

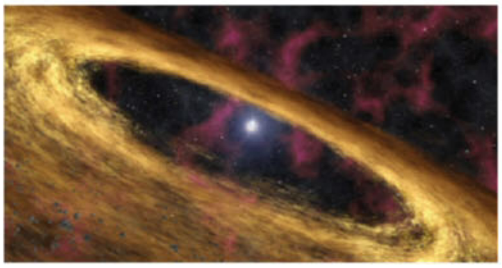
Subsurface flows
Rivers of electrically charged gas carrying magnetic current in the upper convective zone help create photosphere features such as dark sunspots and bright faculae.

Convective zone
The opaque convective zone stretches from the top of the radiative zone out to the Sun's visible radius of 696,000km (432,000mi), where it becomes transparent at the photosphere. Here, energy is transported through rising currents of hot gas, rather than as radiation.

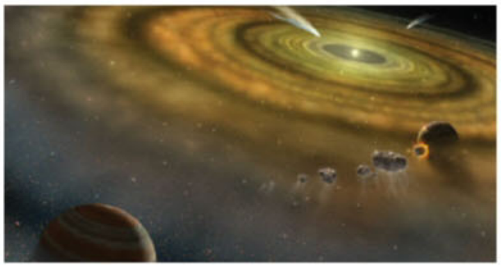
can briefly come close enough for a tremendously powerful short-range attractive force, known as the 'strong nuclear force', to overcome their electromagnetic repulsion.

As a result, the Sun can only sustain fusion in a core occupying about 20 per cent of its diameter. Power released here takes the form of gamma rays – electromagnetic waves similar to the light but with much shorter wavelengths and higher frequencies that allow them to carry much more energy. These rays still have a long journey ahead of them to reach the Sun's visible surface and escape into open space.

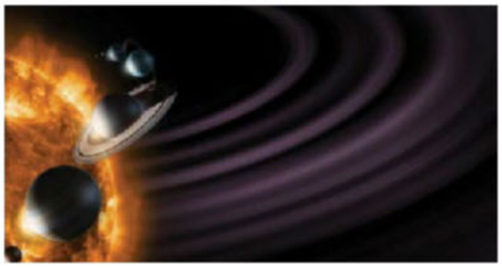
The Sun's interior is divided into three distinct zones – the core, the radiative zone and the convective zone. Not content with pointing to fusion as the likely source of stellar energy, it was Eddington who first theorised the existence of these zones and explained how stars as a whole remain stable, despite the firestorm raging within them. This is thanks to a balancing act called hydrostatic equilibrium: the forces acting on any arbitrary layer within the star, he showed, are always precisely balanced between outward pressure from radiation flooding away from the core, and the inward pull of gravity.



4. Protostar
At first, the Sun shone by radiating energy generated by its own gravitational contraction. It was a large, warm ball of gas surrounded by a ring of debris.

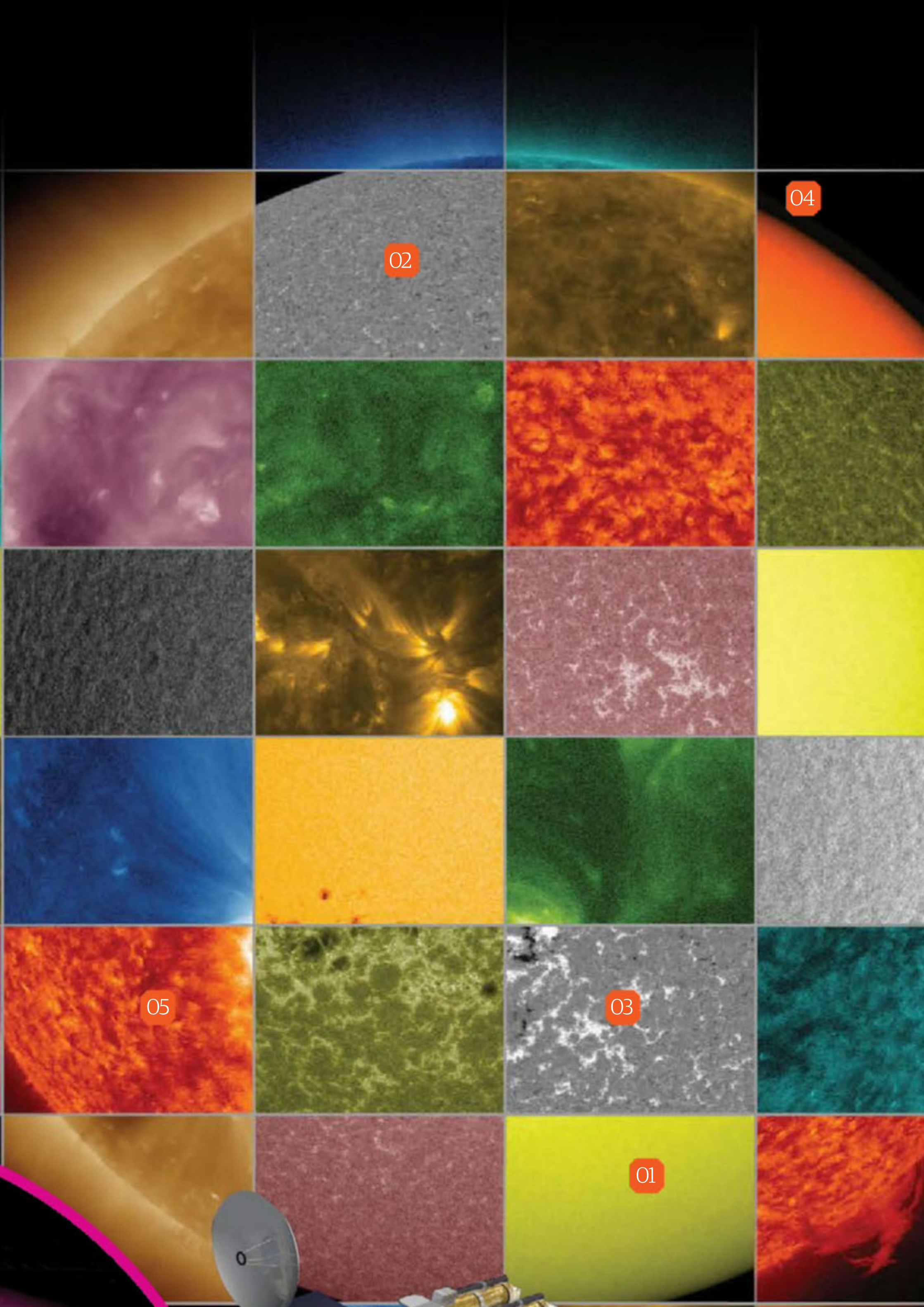


5. Ignition!
The Sun continued to grow smaller and denser, until its core became hot enough to begin nuclear fusion. Meanwhile the debris around it formed into planets.



6. The Solar System today
The Sun is roughly halfway through an estimated 10 billion year lifetime during which it will continue to shine by fusing hydrogen into helium in its core.

Observing the Sun



01 White light

Instrument: AIA (Atmospheric Imaging Assembly)

Light released by hydrogen ions in the photosphere reveals features such as dark sunspots on the visible surface.

02 Shifting surface

Instrument: HMI (Helioseismic and Magnetic Imager)

This 'Dopplergram' highlights areas of the Sun moving towards or away from the instrument, highlighting the pattern of granulation.

03 Magnetic tangle

Instrument: HMI

A magnetogram shows concentrations within the Sun's complex magnetic field – a result of churning currents within the convective zone.

04 Visible continuum

Instrument: HMI

A visible-light image shows both sunspots and traces of granulation. The edge of the Sun appears darker because here we see the cool upper edge of the photosphere.

05 Extreme ultraviolet

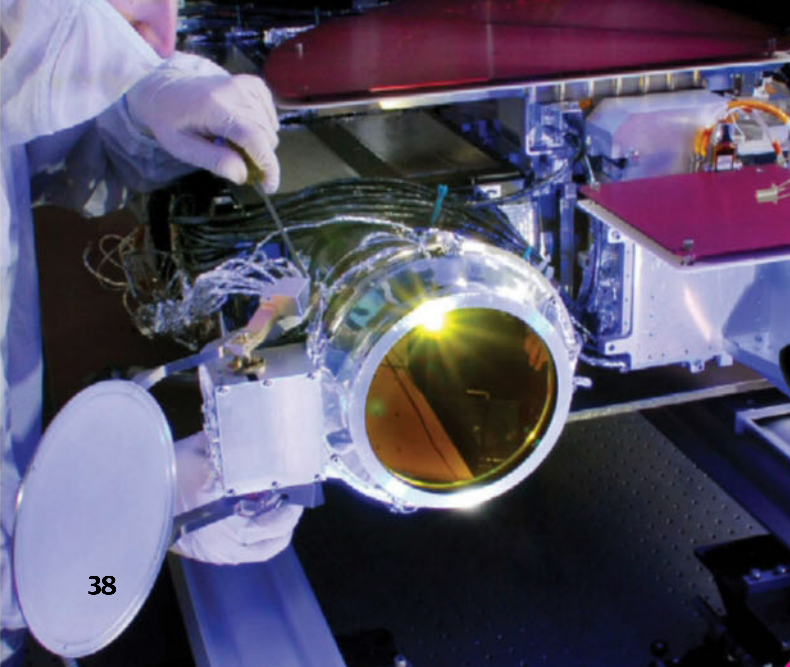
Instrument: AIA

This wavelength shows gases at around 50,000°C (90,000°F), highlighting how the Sun's atmosphere grows hotter again above the photosphere.

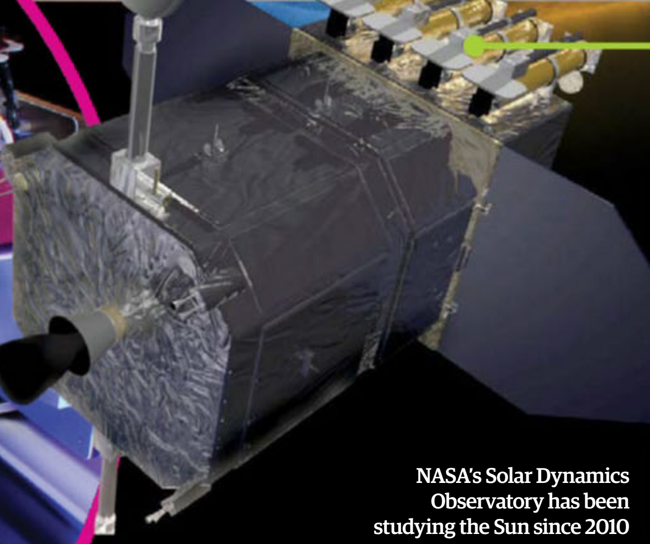
06 X-ray Sun

Instrument: AIA

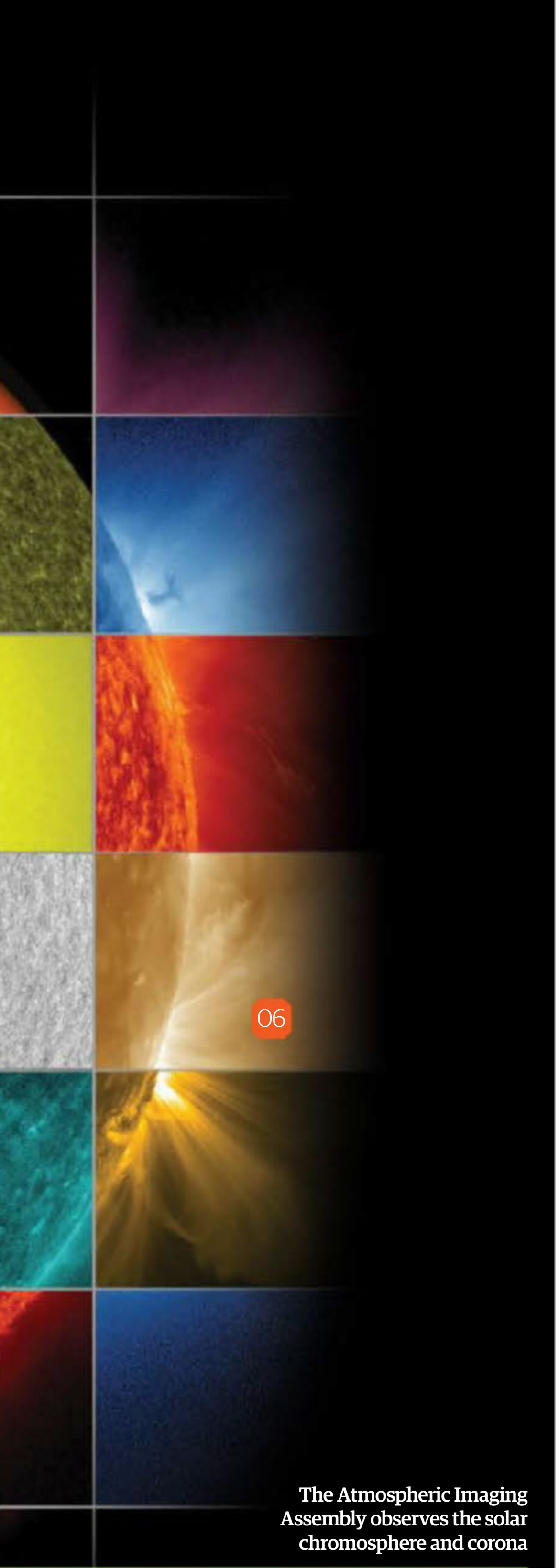
Heated to a million degrees by magnetic forces, the Sun's upper atmosphere or corona emits X-rays that reveal its turbulent structure.



The Helioseismic and Magnetic Imager is designed to study the magnetic field at the solar surface



NASA's Solar Dynamics Observatory has been studying the Sun since 2010



The Atmospheric Imaging Assembly observes the solar chromosphere and corona

As its name suggests, the radiative zone is the region where energy is transferred mainly through radiation (the same is true of the core itself). The sea of particles is so tightly packed that gamma rays can travel for only a very short distance before interacting with something (usually a fast-moving 'free electron'). Each interaction 'scatters' the gamma ray, transferring a little of its energy to the particle and therefore helping to retain the heat of the central regions. Each scattering event sends the gamma ray off in a new direction, and as the gamma rays ricochet from one particle to the next, they follow a long and complicated path known as a 'random walk'.

It might seem as though the gamma rays would be perpetually trapped in the central region, but the very gradual fall-off in density of material from the centre of the Sun outwards ensures that rays are more likely to travel slightly longer distances before scattering, if they move in directions that are away from the centre. Therefore, over countless interactions, the gamma rays gradually lose energy and move into the Sun's less dense upper layers.

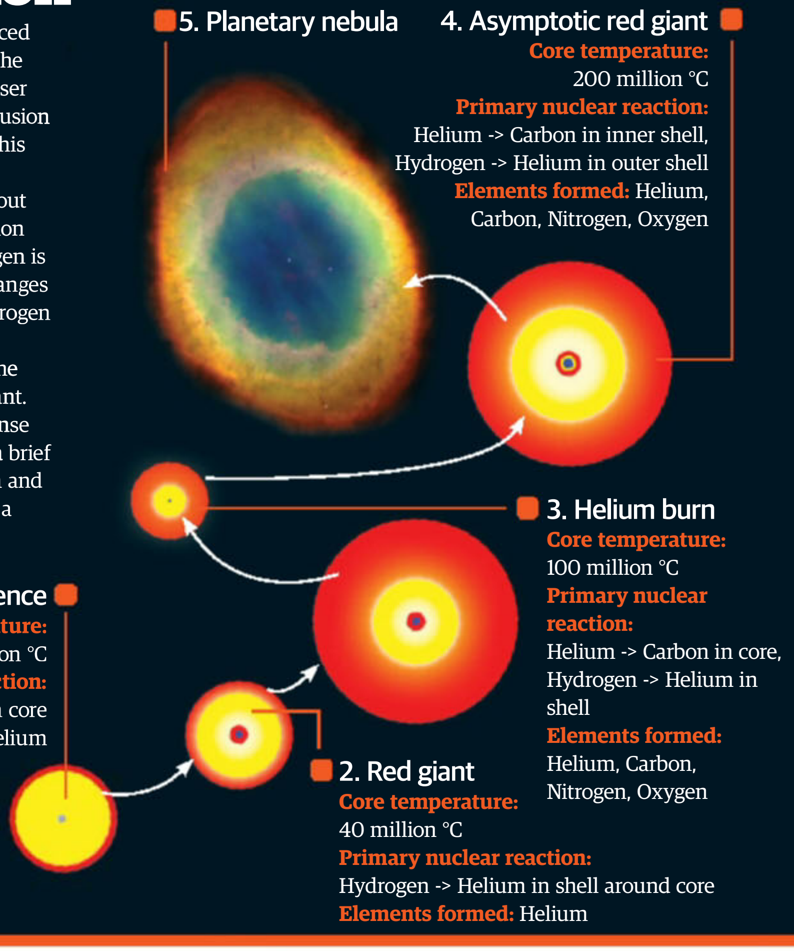
According to the latest models, radiation takes about 170,000 years to travel through the core and radiative zones, moving at an average speed of just 2.9 kilometres (1.8 miles) per year. By the time they reach the upper edge of the radiative zone, 70 per cent of the way to the Sun's surface, the surrounding temperatures have dropped to about 1.5 million degrees Celsius (2.7 million degrees Fahrenheit) and the wavelength of the rays has lengthened considerably - they are now mostly X-rays rather than gamma rays.

Here, at the bottom of the Sun's convective zone, conditions change rapidly from those below. The Sun's materials become more opaque, but also develop a greater ability to absorb heat energy, so radiation ceases to be the most efficient means of transferring energy outwards. Instead, convection (the bulk movement of heated matter) takes over. X-rays heat gas at the bottom of a layer more than 200,000 kilometres (124,000 miles) deep, and as this gas heats and expands, it rises up through overlying cooler gas, taking about ten days to complete the final leg of its journey towards the Sun's surface.

Almost 700,000 kilometres (435,000 miles) from its centre, the Sun's composition changes dramatically once again. As temperatures drop to around 5,500 degrees Celsius (9,932 degrees Fahrenheit), light-absorbing ions that are common in the convective zone disappear, leaving most of the gas in a pure atomic form that is transparent to visible light. Radiation once again becomes the most efficient means for energy to escape, and so electromagnetic rays emitted by the searing gas are no longer reabsorbed and can escape into space.

The future for solar fusion

As hydrogen is slowly replaced by helium in the centre of the Sun, the core will grow denser and hotter, and the rate of fusion will increase in response. This causes the Sun to brighten gradually over time - by about one per cent every 110 million years. Once the core hydrogen is exhausted, more radical changes will take place. At first, hydrogen fusion will move out into a shell around the core and the Sun will swell into a red giant. Later, the core will grow dense enough to fuse helium for a brief phase before swelling again and shedding its outer layers in a planetary nebula.



1. Late main sequence
Core temperature: 20 million °C
Primary nuclear reaction: Hydrogen -> Helium in core
Elements formed: Helium

2. Red giant
Core temperature: 40 million °C
Primary nuclear reaction: Hydrogen -> Helium in shell around core
Elements formed: Helium

3. Helium burn
Core temperature: 100 million °C
Primary nuclear reaction: Helium -> Carbon in core, Hydrogen -> Helium in shell
Elements formed: Helium, Carbon, Nitrogen, Oxygen

4. Asymptotic red giant
Core temperature: 200 million °C
Primary nuclear reaction: Helium -> Carbon in inner shell, Hydrogen -> Helium in outer shell
Elements formed: Helium, Carbon, Nitrogen, Oxygen

5. Planetary nebula

This transition region between the opaque inner Sun and its transparent upper atmosphere can be a few hundred kilometres deep and, if viewed close up, would resemble the gradual clearing of an incandescent fog. However, on the scale of the Sun as a whole, the boundary is very thin, and so the Sun appears to have a sharply defined outer surface called the photosphere.

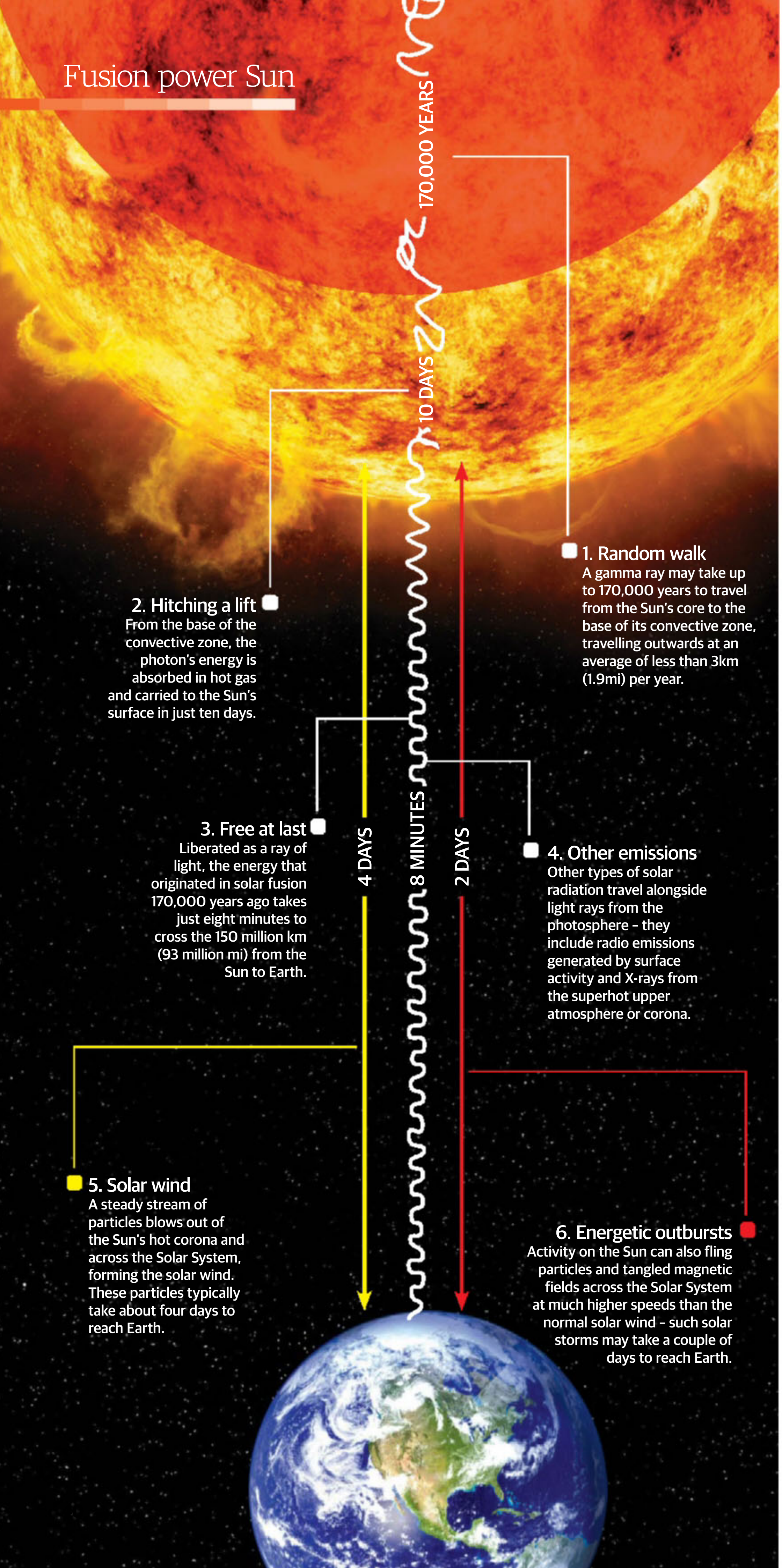
Thanks to the relatively low temperature of the Sun's surface, it releases a mixture of different radiations - ultraviolet rays, visible light and infrared (heat) radiation. These might be comparatively feeble compared to the original gamma rays generated in the core, but the energy they have lost along the way has helped to sustain the Sun's internal power plant.

The Sun's surface and upper atmosphere are the only parts of our star that we can observe directly, but they reveal a great deal about the processes going on within. Viewed through a filter that blocks out most of its blazing light, the photosphere is alive with a seething, shifting pattern of bright, dark-edged spots known as granulation. Each granule marks a single convection cell - the bright spot is formed where rising hot gas radiates its energy away into space, while the dark rim is formed of cooling gas sinking back down towards the interior. Individual granules are a relatively short-lived phenomenon of the upper convection zone - perhaps 1,500 kilometres (932 miles) across and with lifespans of just 15 minutes. However they're supported on deeper and larger 'supergranules', up to 30,000 kilometres (18,600 miles) wide and with lifespans of up to a day.

In addition to these fairly placid, ongoing processes, the photosphere (together with a thin overlying layer called the chromosphere) also develops a variety of more dramatic, intermittent features such as dark sunspots, bright faculae and looping arcs of gas known as prominences. Such features are linked to changes to a solar magnetic field generated within the churning convective zone. These come and go with the waxing and waning of the 11-year solar cycle and are linked to more violent events such as solar flares.

According to most calculations, nuclear fusion should supply enough energy to keep the Sun shining for about 10 billion years before the supplies of fuel in its core are exhausted. So given that the Solar System formed some 4.5 billion years ago, we're about halfway through the Sun's hydrogen-burning lifetime. As the hydrogen starts to run out, physical changes to the structure of our local star will enable it to keep shining for perhaps 2 billion years more, but they will have a profound influence on the entire Solar System and certainly leave Earth uninhabitable long before then.

Today, however, our planet basks in the energy generated by a nuclear furnace 150 million kilometres (93 million miles) away. Happily for us, the radiation the Sun releases at its surface is a lot less damaging to living tissues than that generated in its core - thanks in large part to about 500,000 kilometres (310,000 miles) of shielding in the form of the radiative and convective zones. Life on Earth could not have come into being without nuclear fusion in the Sun, we could not survive without it - and perhaps one day we will even learn to harness it for our own purposes. ■



1. Random walk
A gamma ray may take up to 170,000 years to travel from the Sun's core to the base of its convective zone, travelling outwards at an average of less than 3km (1.9mi) per year.

2. Hitching a lift
From the base of the convective zone, the photon's energy is absorbed in hot gas and carried to the Sun's surface in just ten days.

3. Free at last
Liberated as a ray of light, the energy that originated in solar fusion 170,000 years ago takes just eight minutes to cross the 150 million km (93 million mi) from the Sun to Earth.

4. Other emissions
Other types of solar radiation travel alongside light rays from the photosphere - they include radio emissions generated by surface activity and X-rays from the superhot upper atmosphere or corona.

5. Solar wind
A steady stream of particles blows out of the Sun's hot corona and across the Solar System, forming the solar wind. These particles typically take about four days to reach Earth.

6. Energetic outbursts
Activity on the Sun can also fling particles and tangled magnetic fields across the Solar System at much higher speeds than the normal solar wind - such solar storms may take a couple of days to reach Earth.

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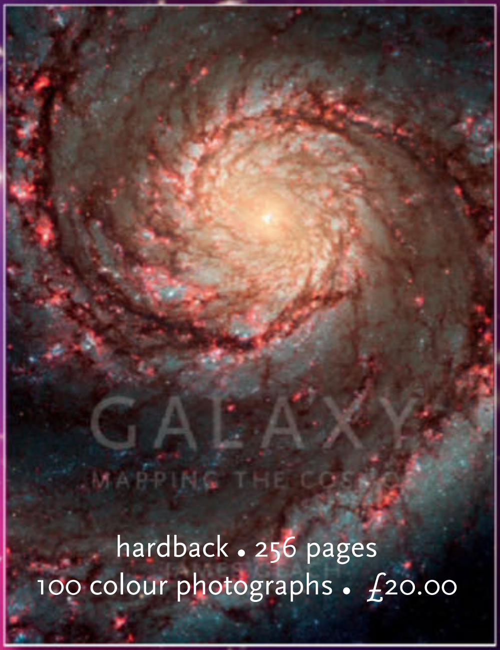
GALAXY

MAPPING THE COSMOS

James Geach



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Space delivery service

400 kilometre-high postage: a same-day delivery system for sending kit from the International Space Station back to Earth

Intuitive Machines, a commercial technology company, in cooperation with NASA, is producing the Terrestrial Return Vehicle (TRV) that will quickly return lab experiments and other perishable materials or time-critical material from space to Earth. Scheduled for deployment in 2016, it will fill a pressing need to carry out exciting new experiments and provide a regular delivery of samples from the International Space Station to Earth. At the moment it is frustrating that these materials can only be sent back a couple of times a year and require a long-winded planning procedure.

The project is managed by the Center for the Advancement of Science in Space (CASIS), which will be responsible for sending the TRVs to the ISS on commercial resupply service vehicles, their in-orbit operations and for their non-flight systems.

Intuitive Machines will design the vehicles, obtain certification for their flight worthiness and organise the recovery and delivery of the payloads to terrestrial laboratories within 24 hours of their departure from the ISS.

The TRV, besides being more convenient, will be cheaper to operate than the large Dragon capsules that are currently used for ISS cargo transfers. They are small enough for several to be sent, stored and used on board the ISS at the same time.

The craft itself looks like a miniature wing-less Space Shuttle. At only about one metre (3.3 feet) long and half a metre (1.6 feet) wide, it is roughly the size of a set of golf clubs. It will carry a payload of five to ten kilograms (11 to 22 pounds) in a space of 30 litres (eight gallons), and to preserve samples the TRV can be configured to carry cold storage compartments. Future TRV craft will also be developed to carry live mice and other small animals.

When experimental samples are ready to be sent back to Earth, they are loaded inside a TRV. It is then transferred to the Japanese Experiment Module (JEM) airlock. On exit from the airlock the TRV is grabbed by the JEM Remote Manipulator System arm, which moves it away from the ISS and releases it when at the correct attitude.

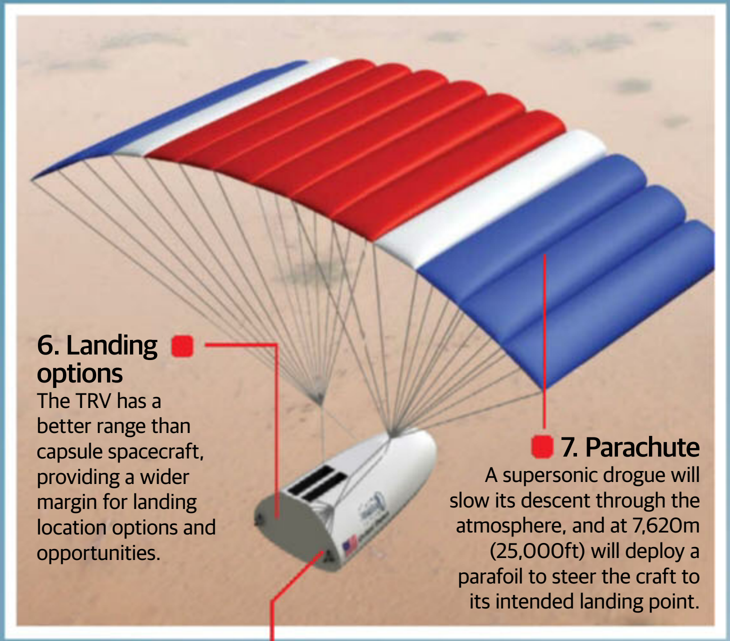
The TRV has its own engines that are powered by warm nitrogen gas at high pressure. The main engine is fired to initiate the re-entry into the Earth's atmosphere, and it uses attitude control jets to guide it accurately toward our planet.

The first TRV landings will be made on a dry lake bed in the Utah desert in the United States. Since it has a lifting body-type aeroshape and a steerable parafoil to guide it through the Earth's lower atmosphere, it is anticipated that in future it will be able to provide a very accurate and flexible range of landing options.

The type of experiments that will benefit from this rapid delivery service range from the study of protein crystal formation to the growth of human tissue. In the microgravity of the ISS crystals are able to grow larger and in all directions, which is extremely useful for pharmaceutical research and development. Similarly, in microgravity samples of human tissue are able to form in three dimensions, whereas on Earth they grow flat due to the effects of gravity. This type of research can provide insights into the growth of cancerous and normal tissues, and facilitate the testing of new drugs.

By getting quick feedback, scientists can use the data for further experiments, more efficiently exploring new areas of study. In essence, the small TRV will have a big impact on the range and type of research conducted on the ISS.

"The TRV will have a big impact on the type of research conducted on the ISS"

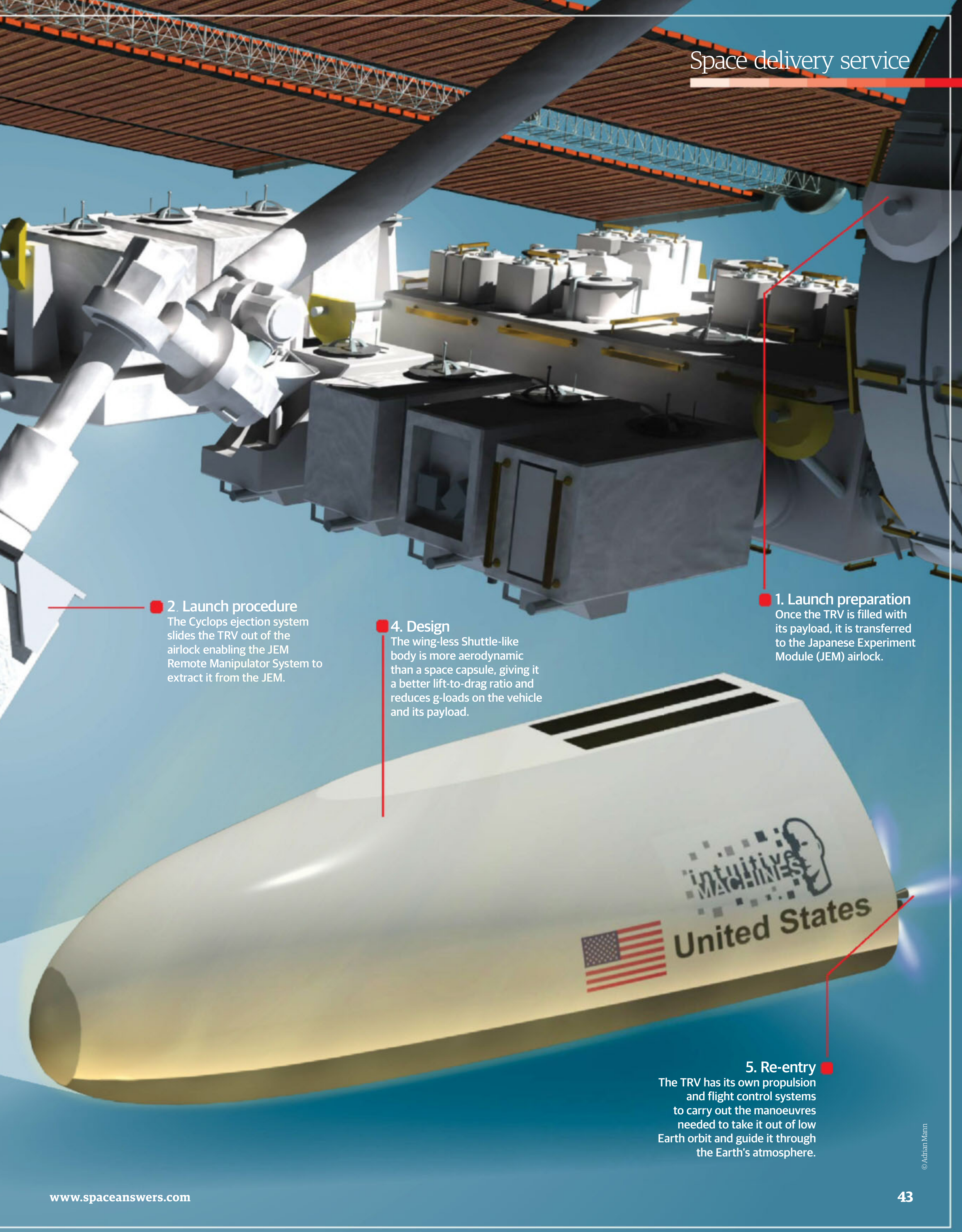


6. Landing options
The TRV has a better range than capsule spacecraft, providing a wider margin for landing location options and opportunities.

7. Parachute
A supersonic drogue will slow its descent through the atmosphere, and at 7,620m (25,000ft) will deploy a parafoil to steer the craft to its intended landing point.

8. Landing
After a six-hour journey from the ISS, the TRV will safely land at a test range in the Utah desert, USA.

3. Launch
When the manipulator system is positioned at the correct attitude the TRV is released toward Earth.



1. Launch preparation

Once the TRV is filled with its payload, it is transferred to the Japanese Experiment Module (JEM) airlock.

2. Launch procedure

The Cyclops ejection system slides the TRV out of the airlock enabling the JEM Remote Manipulator System to extract it from the JEM.

4. Design

The wing-less Shuttle-like body is more aerodynamic than a space capsule, giving it a better lift-to-drag ratio and reduces g-loads on the vehicle and its payload.

5. Re-entry

The TRV has its own propulsion and flight control systems to carry out the manoeuvres needed to take it out of low Earth orbit and guide it through the Earth's atmosphere.

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Preserving our SPACE HISTORY

As we strive to explore and expand beyond the sphere of our own planet, we're leaving a growing trail of artefacts with vital cultural significance along the way. Should we preserve our space history – and how?

Written by: Paul Cockburn

Few people – except for certain conspiracy theorists – are likely to dispute that genuine history was made on 21 July 1969 when Neil Armstrong made the first human footprint on the surface of the Moon. Even today, the technological achievements of the United States space agency NASA and its Apollo space programme – fulfilling President Kennedy's 1961 commitment to "landing a man on the Moon and returning him safely to the Earth" before the end of the decade – remains a landmark of human achievement.

So it surely follows that the location of those first human steps on another stellar body are of historic importance too, and should be preserved for the future. Yet it's only in the last decade that the issue has gained serious attention from archaeologists and historians. Nor are we just talking about the Apollo missions. The still relatively new field of space archaeology potentially covers every aspect of humanity's exploration and use of space, from the probes we've sent out to the edge of our Solar System to the geostationary satellites on which so much of our everyday lives now depend – as well as the launch systems and technology used to get them beyond the Earth's atmosphere.

"All of this material culture represents the technological stage of humankind at a particular stage of our evolution and history," insists Dr Beth O'Leary, Professor Emerita in anthropology at New Mexico State University. "The artefacts and sites are symbolic of the political, social and economic history of the world during this early space age. Although scientific in nature, space archaeologists look at the meaning and significance of objects and sites. I rank our first lunar landing right up there with the discovery of fire."

So, if your idea of an archaeologist is either Harrison Ford with a fedora and a whip, or of eccentric people using small trowels and brushes to uncover artefacts and skeletons buried for thousands of years around the world, then you may well be surprised to learn that some are now turning their attention to space.

"A good definition of archaeology is the study of the relationships between patterns of material culture and patterns of human behaviour," Dr O'Leary says. "It sets no temporal or spatial limits. It can be done in all times and in all places. Space archaeology and heritage is the study of material culture that is relevant to space exploration that is found on Earth and in outer space."

So why the growing concerns about preservation? "Archaeology, unlike other disciplines, cannot exist without the material remains of human behaviour," she adds. "The exploration of space has a material culture that is as relevant to the development of human culture and human evolution as the earliest stone tools 2.5 million years ago.

"Study of the material record, which includes examples of technology, is an essential way to understand how and why humans create and adapt technology to explore even such extreme environments such as space. If the material remains are absent, destroyed, looted or not preserved, we

INTERVIEWBIO

Dr Beth O'Leary
Professor Emerita in anthropology, New Mexico State University

Beth has been involved with the cultural heritage of outer space for the last 14 years. With NASA support she has investigated both the archaeological assemblage and the international heritage status of the Apollo 11 Tranquility Base site.

lose the ability to understand humans from a unique and important perspective."

It's less than 30 years since Brown University archaeologist Richard Gould first proposed that aircraft wrecks might provide important information, laying the foundation for systematic archaeological studies of human flight. As recently as 1993, University of Hawaii anthropologist Ben Finney – who has spent much of his career examining the technology and techniques used by early Polynesian colonisers in the Pacific – suggested that we should start thinking about Russian and American sites on the Moon and Mars. While archaeologists are currently unlikely to be in a position to conduct proper fieldwork at those sites in the foreseeable future, that doesn't mean they – or unscrupulous treasure hunters – never will.

We know that Armstrong's footprints on the Moon and those made by fellow astronaut Buzz Aldrin are still there; in 2012 NASA's Lunar Reconnaissance Orbiter (LRO) took pictures of the site from just 24 kilometres (15 miles) above the surface and confirmed it was essentially as the astronauts had left it – hardly surprising given that, unlike Earth, there's no atmosphere to erode or disturb anything.

At the moment, only an extremely unlucky meteorite strike is likely to destroy those unique first human footprints in the lunar dust. However, because we're potentially on the verge of a new space age that will see both commercial and government missions to the Moon, Dr O'Leary believes that ways must be found to evaluate and preserve such "critical phases of space exploration". We can't, in other words, always rely on the Apollo sites being safe from future human activity simply because they're 384,400 kilometres (238,855 miles) away from Earth.

Ironically enough, the biggest challenge space archaeologists face in terms of preservation is legal. "It is a question about who owns space," Dr O'Leary explains. "According to the Outer Space Treaty of 1967, no nation or state can claim the surface of the Moon or other celestial bodies, and space is regulated as a place for peaceful purposes. The Outer Space Treaty also states that the nation or state that puts objects and/or personnel in space or on other celestial bodies maintains responsibility and ownership of such. There is a whole field of space law that, by multinational and multilateral agreements regulates (albeit in a piecemeal fashion) the launching and positioning of space vehicles such as satellites. In the research I have done, these agreements and treaties do not address the preservation of cultural resources in space or on any celestial body.

"In 2000, during my work on the Lunar Legacy Project, we contacted NASA and the Keeper of the National Register of Historic Places to nominate the Tranquility Base site on the Moon as a National Historic Landmark," she adds. "The response from both was that making these part of the US preservation system would be perceived by the international community as a claim of sovereignty over the surface of the Moon, and the Keeper further felt that federal historic preservation law did not have jurisdiction over sites on the lunar surface as they were not on American soil."

In 2011, NASA recognised the need to address preservation on the lunar surface and included Dr

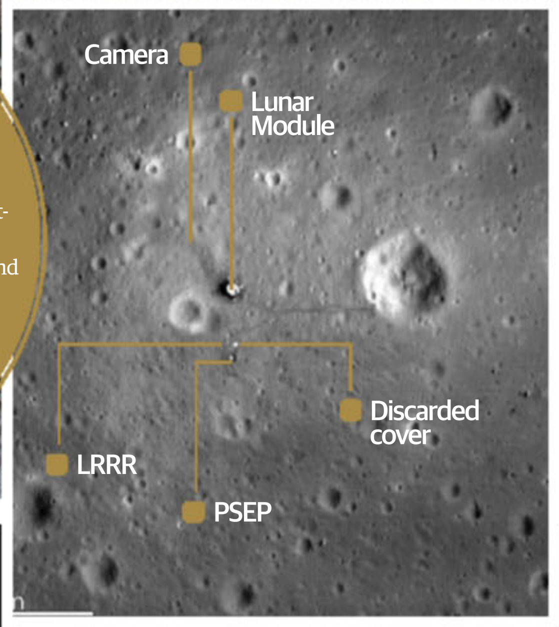
Neil Armstrong makes history – and leaves artefacts for posterity on the Moon

Apollo 11 landing site

Mare Tranquillitatis, the Moon

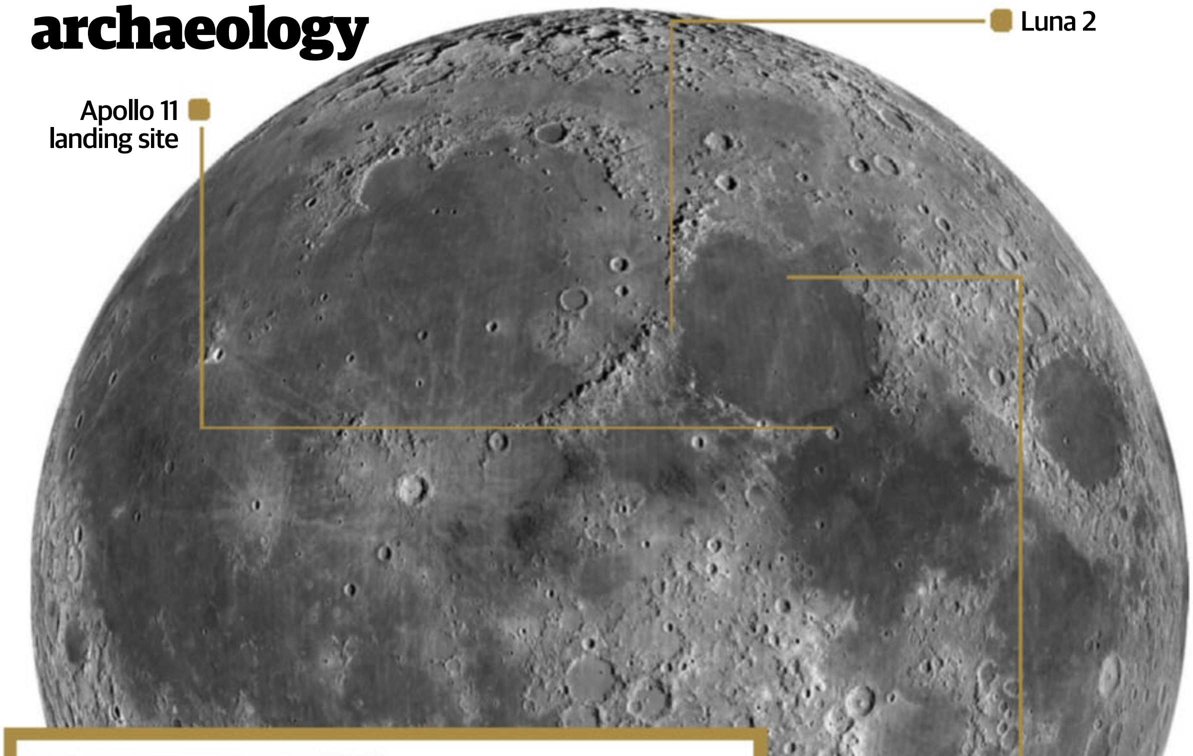
First human lunar landing

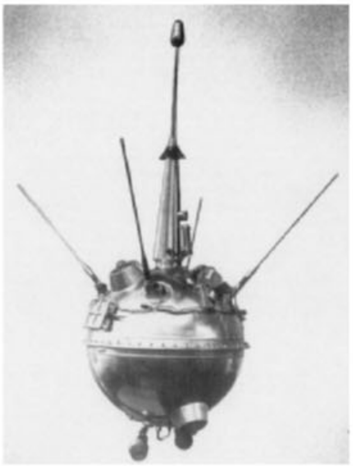
According to astronaut Neil Armstrong, Tranquility Bay had "a stark beauty all its own", but the landing site remains the longest-operating non-terrestrial scientific base – the Laser Ranging RetroReflector (LRRR) left behind by Apollo 11 enables precise measurements of the Moon's distance from the Earth to be collected to this day. Frankly, though, it's also a bit of a mess, with items (such as the LRRR cover) just thrown away by the crew.



Cernan and Schmitt collect samples in the last human landing place on the Moon

Earth-Moon archaeology





Luna 2

Mare Serenitatis, the Moon

First lunar landing

The USSR's robotic Luna 2 probe was the first human-made object to 'land' on another celestial body (near the Aristides, Archimedes, and Autolycus craters), albeit at speed, and presumably leaving its mark with an impact crater. Luna 2's known instrumentation – including geiger-counter, magnetometer and micrometeorite detectors – confirmed that the Moon had no appreciable magnetic field or radiation belts. But, given this was during the Cold War, was any other technology on board?

Lunar Historical Park?

On 8 July 2013, United States Congresswoman Donna F Edwards introduced a bill in the House of Representatives - numbered HR 2617 - which proposed to "establish the Apollo Lunar Landing Sites National Historical Park on the Moon", in part to "expand and enhance the protection and preservation of the Apollo lunar landing sites and provide for greater recognition and public understanding of this singular achievement in American history".

The bill also committed the US Department of the Interior to submit the sites to UNESCO (United Nations Educational, Scientific, and Cultural Organization) for designation as World Heritage Sites. However, the bill was not brought before the Congress for a vote, in part because of criticism that it could be seen as a claim of US sovereignty over the Moon.

> "I rank our first lunar landing right up there with the discovery of fire"
>
> **Dr Beth O'Leary**

Apollo 17 landing site

Taurus-Littrow valley, the Moon

Last human landing place on the Moon (for now)

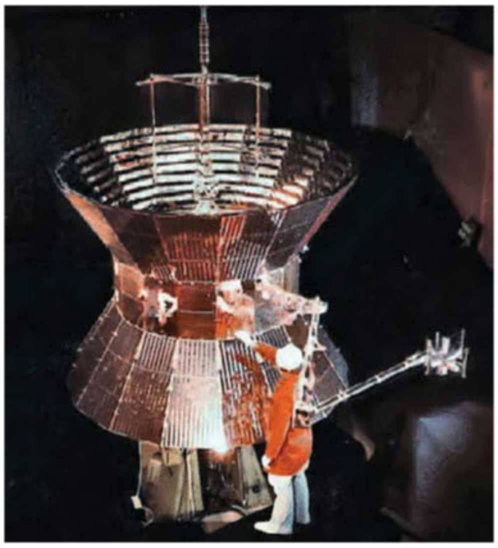
Astronauts Eugene Cernan and Harrison Schmitt spent three days on the surface, collecting samples and travelling almost 36 kilometres (22 miles) in their Lunar Roving Vehicle. The abandoned stage of the Lunar Module includes a plaque signed by the mission's astronauts and then US President Richard Nixon: "Here Man completed his first explorations of the Moon, December 1972, AD. May the spirit of peace in which we came be reflected in the lives of all mankind."

Deep Space 1

Solar orbit

NASA's first ion-powered rocket

Deep Space 1 was the first technology demonstration probe created by NASA's New Millennium Program; in addition to its payload equipment, the technology demonstrated by the craft included its own xenon ion engine. The craft's ion engines were shut down on 18 December 2001, though its radio receiver was left on in case any future contact was required.

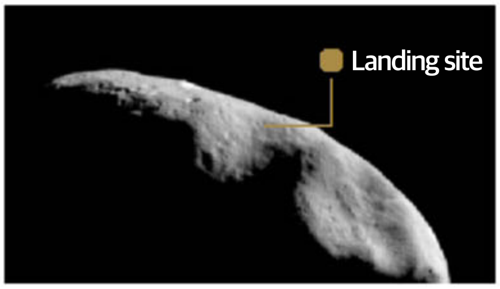


Helios probes

Solar orbit

Fastest, closest flyby of the Sun by any spacecraft

Helios-A and Helios-B (aka Helios 1 and Helios 2) were a joint venture between what was then West Germany and NASA to study solar processes nearer the Sun, both passing inside the orbit of Mercury. Launched in December 1974 and January 1976 respectively, the probes continued to send data up to 1985 and, while no longer functional, remain in their elliptical orbit around the Sun.



NEAR Shoemaker

Near-Earth asteroid Eros

First soft-landing on an asteroid

Launched in 1996, the Near Earth Asteroid Rendezvous – Shoemaker was designed to study the asteroid 433 Eros from close orbit over a period of a year. Despite various software problems, NEAR Shoemaker gathered significant amounts of data before making a successful touchdown on the asteroid.

> "The astronauts unintentionally became the first extraterrestrial archaeologists"

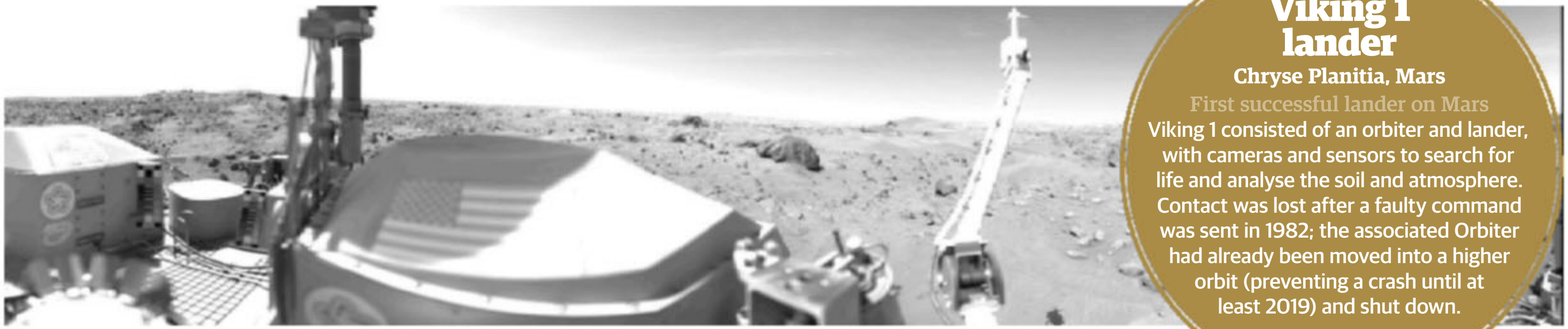
O'Leary in the team, which subsequently issued NASA's Recommendations to Space-Faring Entities. However, while several commercial operations have agreed to its guidelines, they are not legally binding. "Space archaeological sites as well as objects – fall into a grey legal area as preservation was not seen as an issue when national and international laws and agreements were drafted," explains Dr O'Leary. "Space and celestial bodies are perceived as a commons."

Another challenge is that not everything is of archaeological interest, even though most of it is located between 160 kilometres (99 miles) and 2,000 kilometres (1,243 miles) away in low Earth orbit. From flecks of paint and metal fragments, to spent rocket stages and old satellites, this orbital space debris – a potential danger to current and future space missions – also contains 'significant' objects that warrant protection, like Vanguard 1, the US satellite launched in 1958 that's currently the oldest human object still in orbit. "We do not currently have a cohesive way of evaluating the significance of the 'space junk'," accepts Dr O'Leary, "which is an obvious first step in considering whether to discard or preserve it.

"Not everything can and should be preserved, or be considered 'significant' and warrant protection," she adds. "That doesn't happen on Earth. Frequently in the presence of redundant debris, the debris is sampled and that sample is part of a preservation strategy. Space junk is a serious problem in low Earth orbit, but not all space junk is just garbage; there are some historic spacecraft still there that represent the technological, political and social exploration of space. The evaluation of this cultural heritage has barely been considered."

Some space missions are potentially luckier; there are fundamental mission reasons for locating the new James Webb Space Telescope in an elliptical orbit about the second Lagrange point (so that the gravitation forces of the Sun, Earth and Moon will hold it in a stable location), but this could also ensure the safe survival of the infrared telescope well beyond its planned lifespan.

However, 'future curation' to preserve historical artefacts has yet to be included in any space mission. "If there are decisions to be made about what should



Viking 1 lander

Chryse Planitia, Mars

First successful lander on Mars

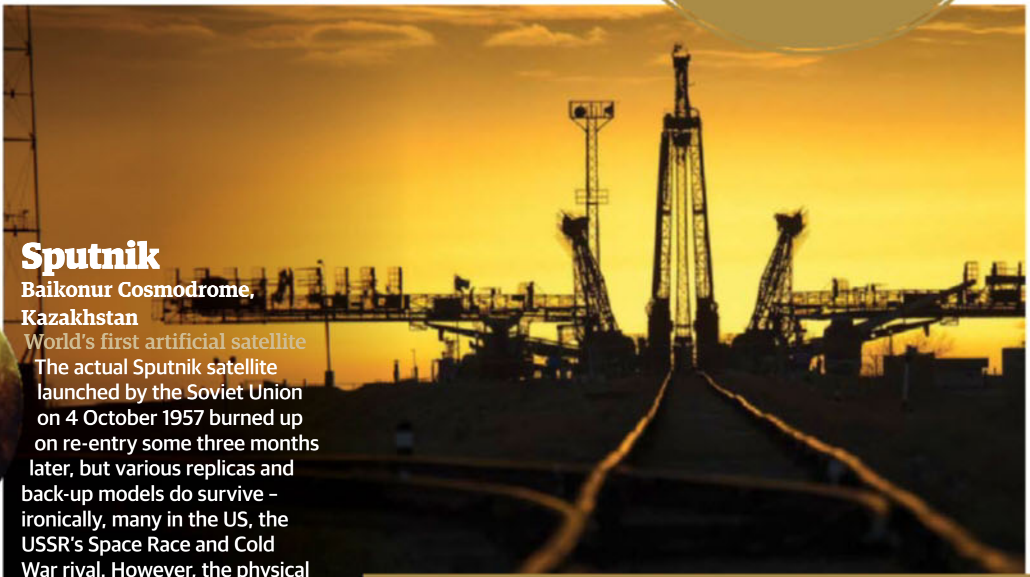
Viking 1 consisted of an orbiter and lander, with cameras and sensors to search for life and analyse the soil and atmosphere. Contact was lost after a faulty command was sent in 1982; the associated Orbiter had already been moved into a higher orbit (preventing a crash until at least 2019) and shut down.

Voyager 1 & 2

Outside the Solar System

Most distant human objects

According to Peter Capelotti, a Professor of Anthropology at Penn State University, there remains a tiny chance these interstellar probes might become "archaeological representatives of Homo sapiens to the rest of the galaxy". Yet they also remain a 'snapshot' of humanity at the time of their launch in 1977, thanks to their gold-plated audiovisual discs.



Sputnik

Baikonur Cosmodrome, Kazakhstan

World's first artificial satellite

The actual Sputnik satellite launched by the Soviet Union on 4 October 1957 burned up on re-entry some three months later, but various replicas and back-up models do survive – ironically, many in the US, the USSR's Space Race and Cold War rival. However, the physical results of all the engineering know-how and technological developments which made the launch possible can still be found at the world's original space launch facility – which remains heavily in use today.

Huygens probe

Titan

First successful landing in the outer Solar System

The 2005 Huygens probe was the European Space Agency's contribution to a joint NASA/ESA/ASI mission to investigate Saturn and its moons; initially attached to the Cassini probe, Huygens became the first successful landing (on 14 January 2005) in the outer Solar System, and remains the most distant landing site for any craft.

Venera 1

Heliocentric orbit

First spacecraft to flyby Venus

Launched on 12 February 1961, Venera 1 was the first in a succession of Soviet missions to Venus; unfortunately, although it became the first human-built spacecraft to fly past another planet the following May, contact had been lost just seven days after the probe launched, so no data was received.

be destroyed or removed it should be done so that 'precious artefacts' should be left in their natural setting, given the risk factors for collision or damage," says Dr O'Leary. "These decisions need to be informed by the field of space archaeology.

"Governments, commercial entities and researchers all need to get involved in preservation decisions," she adds. "There needs to be multinational and multilateral cooperative decisions by those space-faring entities; the USA, Russia, Japan, ESA and China have separate and mutual interests in preserving this legacy of wonderful things in order to allow for the study of the space age."

Readers keen to become the first space archaeologists, however, are too late. In November 1969, Apollo 12 astronauts Charles 'Pete' Conrad and Alan Bean landed their Lunar Module in the Oceanus Procellarum ('Ocean of Storms'), just a few hundred feet from the crater in which unmanned probe Surveyor 3 had soft-landed two-and-a-half years earlier. As part of their mission, the astronauts unintentionally became the first practitioners of extraterrestrial archaeology; they found the remnants of the device, carefully photographed the impressions made by its footpads and then removed the probe's television camera, remote sampling arm, and pieces of tubing – items which were bagged, labelled and stored alongside the mission's geological samples.

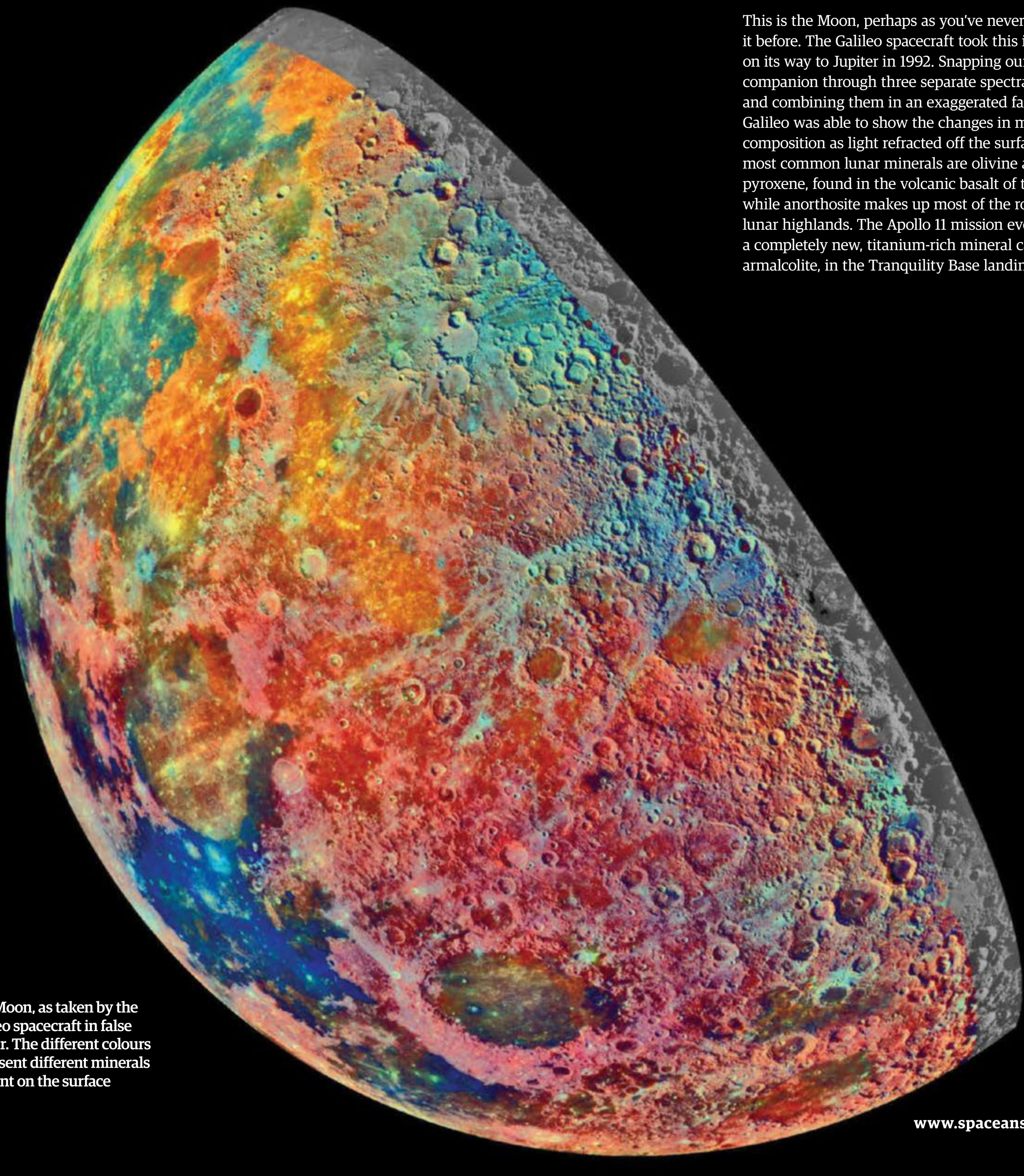
In 1972, NASA published its 'Analysis of Surveyor 3 Material and Photographs Returned by Apollo 12', which focused on the ways the retrieved components had been changed by the craft's voyage through the vacuum of space. The most surprising finding was evidence of the bacteria Streptococcus mitis on part of the camera. Obviously this was not of extraterrestrial origin and, eventually, it was concluded that someone had sneezed on the device.

So it could be said that space archaeology's first great discovery could well be that a bacteria had travelled to the Moon in an alternating freezing/boiling vacuum for two and a half years, and returned promptly to life upon reaching the safety of a Petri dish back on Earth. It would seem that not even the hostile vacuum of space could stop humans from spreading a sore throat! ●

Massive Moon minerals

What did Galileo see when it looked at 73 billion trillion kilograms of lunar rock?

This is the Moon, perhaps as you've never seen it before. The Galileo spacecraft took this image on its way to Jupiter in 1992. Snapping our lunar companion through three separate spectral filters and combining them in an exaggerated false colour, Galileo was able to show the changes in mineral composition as light refracted off the surface. The most common lunar minerals are olivine and pyroxene, found in the volcanic basalt of the maria, while anorthosite makes up most of the rock in the lunar highlands. The Apollo 11 mission even found a completely new, titanium-rich mineral called armalcolite, in the Tranquility Base landing site.



The Moon, as taken by the Galileo spacecraft in false colour. The different colours represent different minerals present on the surface

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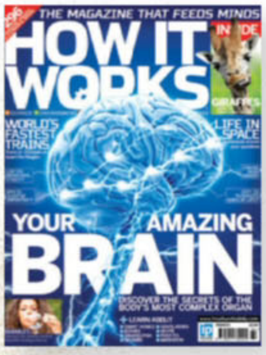

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OUTPOST EARTH

From spacewalking in water to living in the desert, we look at how astronauts train for the challenges of exploring moons, asteroids and planets on Earth

Written by David Crookes

On 4 November 2011, six triumphant men from across the world returned to Earth and emerged from a windowless isolation chamber to elated cheers. They had - in theory at least - been to Mars and back on a journey that had taken them away from their friends and families for 520 days. During that time, three crew members had spent 30 days on the Red Planet, having detached from their mother ship to explore the Martian surface, removed soil and rock samples and planted three flags; one each for the Chinese, Russian and European space agencies.

Their time away proved tough. The mission affected their sleep patterns; one crew member's body ended up falling into a 25-hour day cycle. And although they had books, DVDs and the videogame *Guitar Hero* to occupy them, they had become bored and demotivated by the monotonous journey. Their activity levels lowered, their body temperature dropped by an average of 0.4 degrees Celsius (32.7 degrees Fahrenheit) and they were at risk of bone and muscle wastage. They may have lived in harmony but the three Russians, two Europeans and one Chinese were, it could be surmised, spaced out at least some of the time.

And yet the six hadn't actually ventured away from Earth at all. Their spacecraft was nothing more than a series of steel tubes at the Russian Institute for Biomedical Problems in Moscow. The landing module was also a cylinder that had been made to feel like a Mars landing ship. The planet surface was simply a large room with a high, domed ceiling and a floor covered by red sand and rocks over which the crew had walked dressed in Orlan spacesuits. Everything had been a test, albeit one carefully constructed to be analogous to the expected isolation and challenge of a round trip to Mars.

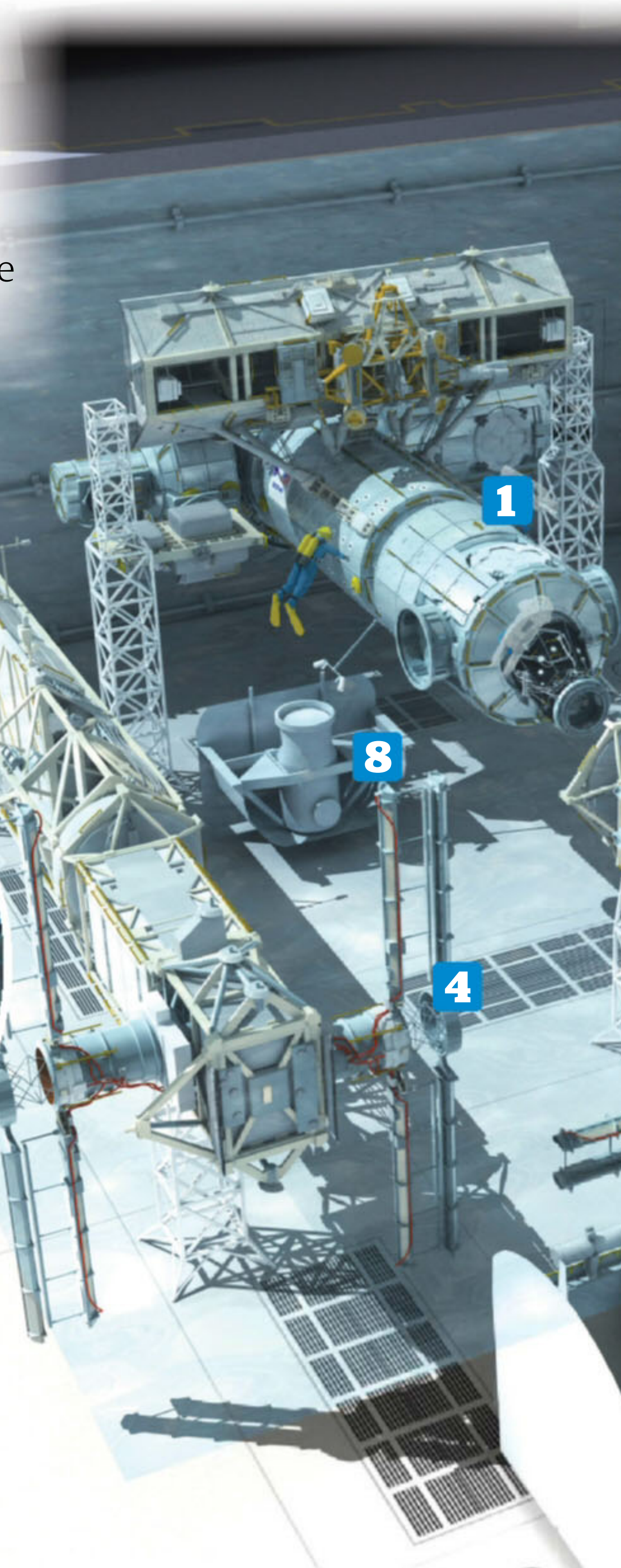
Called Mars 500, the analog mission was of great use to scientists, engineers and astronauts preparing for a real-life future mission to Mars. By observing the experience of the crew, examining their physical and mental health and testing new technologies, experts were able to learn many lessons vital for round trips to the Red Planet. “We were able to simulate the isolation astronauts would feel,” explains Jennifer Ngo-Anh, ESA’s Mars 500 programme manager. “The main purpose was to study whether, from a survival and interpersonal point of view, we could put a crew of six in a spacecraft for such a long time. We were looking at the psychology of the crew, their social interaction and cultural differences. We wanted to know how they would cope with the life support system we had in place and a limited water supply. The only things that were missing were simulations for microgravity and radiation.”

Mars 500 is one of many analog missions - some of which also create artificial, simulated conditions. But analog missions also make use of the extreme environments found on Earth. One such mission is NEEMO, or NASA Extreme Environment Mission Operations. It involves sending six aquanauts to live underwater in a laboratory called Aquarius, some 5.6 kilometres (3.5 miles) from the shore of Key Largo in Florida. There they are isolated but they also get to experience reduced gravity in what is the world’s only operating undersea lab.

Aquanauts can spend as long as three weeks on a NEEMO mission, living and working underwater. For missions on the bed of the ocean, they wear diving suits and oxygen tanks in place of spacesuits. They embark on seawalks that, just like a spacewalk, are carefully planned and restricted in time. Their mobility is slowed and their movement is difficult, mimicking the effort they would need to make when exploring a planet like Mars. In doing this, NEEMO is able to simulate Moon and asteroid missions, testing equipment and operational concepts.

Training for microgravity

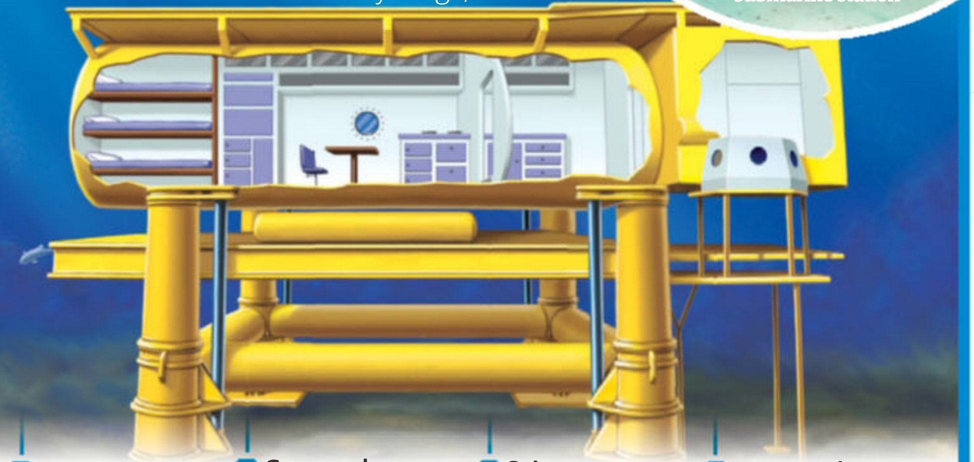
The Neutral Buoyancy Lab facility is a large indoor pool that contains full-sized mock-ups of the International Space Station



NASA Extreme Environment Mission Operations (NEEMO) trains astronauts at the Aquarius submarine station

Asteroid mission preparation

Aquarius is the world’s only submarine research station, found in 19 metres (62 feet) of water off the shore of Key Largo, Florida



Aquanauts
Six aquanauts live and work in pressurised conditions for up to three weeks. They sleep on bunks and have an ocean view.

Cramped space
Aquarius is an 85-ton, double-lock, sub-aquatic laboratory. The main lock contains a kitchen and relaxation space.

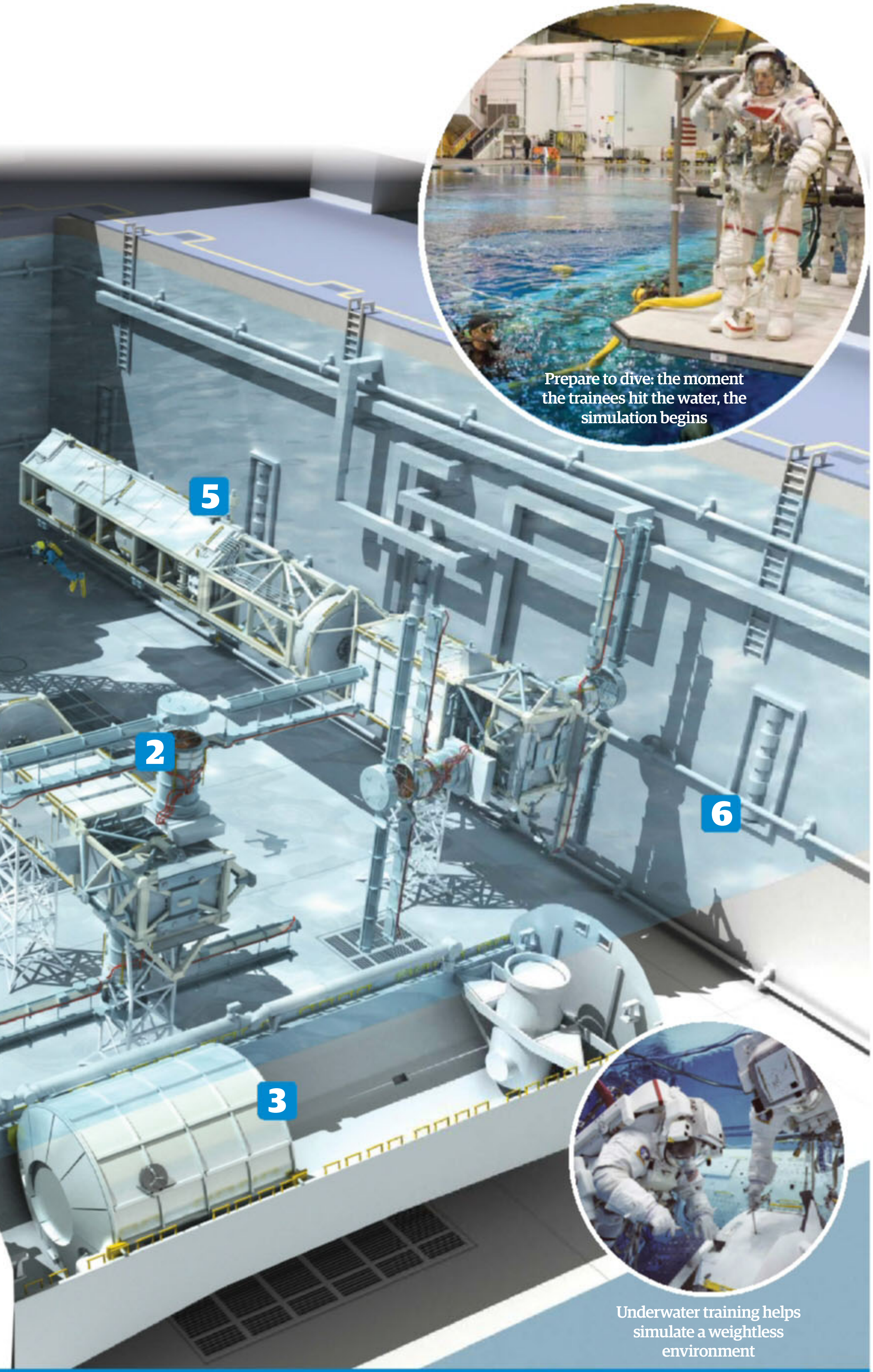
Science area
The entry lock includes workstations and life support. It houses lab equipment and a toilet that connects to a sewer.

Wet porch
Aquanauts come and go via the wet porch, which is open to the ocean. Aquanauts need 15 hours of decompression on exit.

1. The US lab
A replica of the ISS still doesn’t fit directly into the pool. It is bent into the so-called wishbone configuration we see here.

2. P6 segment
By allowing astronauts to view the segments of the ISS’s truss (backbone), they can familiarise themselves with its structure.

3. Cargo bay
This part of the ISS mock-up shows the cargo bay of the Space Shuttle Orbiter, which is used to deploy to or retrieve payloads from Earth.



Prepare to dive: the moment the trainees hit the water, the simulation begins

Underwater training helps simulate a weightless environment

4. S4 segment
As astronauts approach these segments underwater, they will experience the weightless environment of space.

5. P1 segment
Water is the best environment for spacewalk training on Earth. Being able to move in their suits, use handrails and pass objects is vital.

6. NBL tank
The Neutral Buoyancy Laboratory tank is a huge 62 metres (202 feet) long, 31 metres (102 feet) wide and 12 metres (40 feet) deep.

7. The ISS
The ISS is 110 by 73 metres (361 by 240 feet). In the NBL, astronauts can practise installing and maintaining components in space.

8. Docking system
When a shuttle docks with the ISS, it is important that a secure connection is achieved. Astronauts can practise it here.

What is microgravity?

In space, gravity exists but in a reduced form. On the International Space Station, for example, gravity is around 88 per cent of that found on the Earth. But because astronauts are in free fall they appear to float. That's because free falling means they are falling towards and yet around Earth. This is thanks to the pull of the Earth and the speed at which the ISS and spacecraft are moving to match the curvature of the Earth. Referred to as microgravity, it can happen inside a spacecraft or outside on a spacewalk. By simulating microgravity, even for a limited time, astronauts can be better equipped for real-life space missions.

Hervé Stevenin

EVA and Zero-G instructor for ESA astronauts

Hervé Stevenin leads ESA's Neutral Buoyancy Facility Operations. With more than 20 years of training experience, he is a spacewalk instructor for European astronauts.

All About Space: Why is underwater training useful for astronauts?

Hervé Stevenin: Astronauts have to perform EVAs and so we need an environment of weightlessness. Although we can use reduced gravity aircraft, they only give astronauts 23 seconds of pure weightlessness or microgravity. This is not appropriate for EVAs because they are six hours long and astronauts have to work on modules and in a complex environment. So we use an underwater environment to simulate the weightlessness and the astronauts feel like they are in a controlled buoyancy environment.

AAS: How closely can simulation match real life?

HS: The astronauts can work in a big water tank into which we submerge big modules of the station. The modules are full scale and they have all of the EVA-related equipment like handrails on them. The astronauts can use the same kind of tethers and tools for the work underwater that they would carry out in space outside a station so it's equally demanding psychologically and physically. We teach astronauts to be efficient in the way they work. They need to be aware of the environment and communicate well. Not all astronauts can do an EVA: NASA and the Russians put all astronauts through a basic EVA training programme and they then assess who are the best ones. Only the best will continue.

As part of the analog mission, aquanauts will spend a lot of time in a purpose-built habitat. All six will live together in cramped conditions and their ability to work together and support each other is closely studied. Each crew member is trained to deal with fire in the module as well as potential toxicity in the atmosphere.

While two Aquarius technicians are responsible for maintaining the habitat and also live with the astronauts, and while there are safety divers accompanying the crew, part of the analog mission is to limit outside assistance, with communication channels delayed by five minutes. The sense of isolation is also very real: travelling back to the sea surface is arduous and it requires aquanauts to undergo a 16-hour decompression sequence in order to protect the crew members from falling ill with decompression sickness.

"It takes even more time to come back to the surface than it takes to get back from the International Space Station to Earth, so this means the risks are real," says Hervé Stevenin, who was selected to be a crew member of the NEEMO 19 mission in September 2014.

By ensuring there is no quick 'get out', the mission is able to test the resolve of the aquanaut and his or her ability to be an astronaut. They are given a full flavour of the scientific tasks they are expected to carry out too, drilling down into the sea ground to collect samples. Sometimes the crew members are separated and sent to different landmarks, allowing them to recognise geological features of interest to the exploration. They are asked to take distance measurements and the dimensions of items they are studying. They have to send images and video from their helmet cameras to mission control. "It really gives you a feel of what it is like to be a space crew member," says Stevenin, who also leads ESA's Neutral Buoyancy Facility Operations. But it also lets the mission leaders figure what works effectively and what needs to be re-examined.

There are also secondary objectives. Scientists can conduct human physiology experiments during a NEEMO mission, which helps when optimising the planning, technology and expectations of science research during space explorations. With planned human crewed missions to Mars, such analog missions will certainly prove useful when training the next generations of space explorers.

As well as using Aquarius, NASA has an enormous 22.7 million litre (6.2 million gallon) pool located at the Sonny Carter Training Facility near NASA's Johnson Space Center in Houston, Texas. Called

Loredana Bessone

CAVES course and mission director

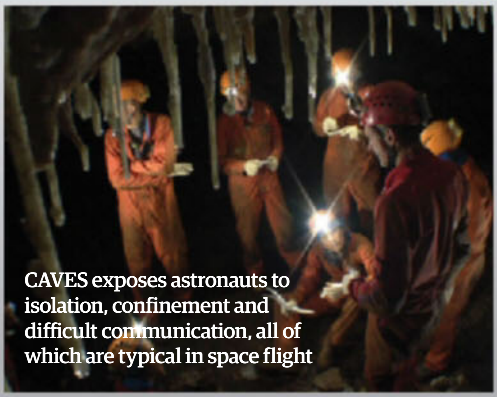
Loredana was hired by ESA for a student job in 1990 and within a few years had begun work on human space flight. She went on to develop astronaut operational skills training including ESA's CAVES.

All About Space: What were you looking for when you developed CAVES?

Loredana Bessone: I was looking for an environment very similar to that which astronauts would encounter during human space flight so I wanted isolation, confinement, limited resources and difficult communication. There had to be real risk to create stressors that are typical on human space flight and a real mission that would allow astronauts to work together effectively and safely as an international team.

AAS: How can you be sure simulations match real life experiences?

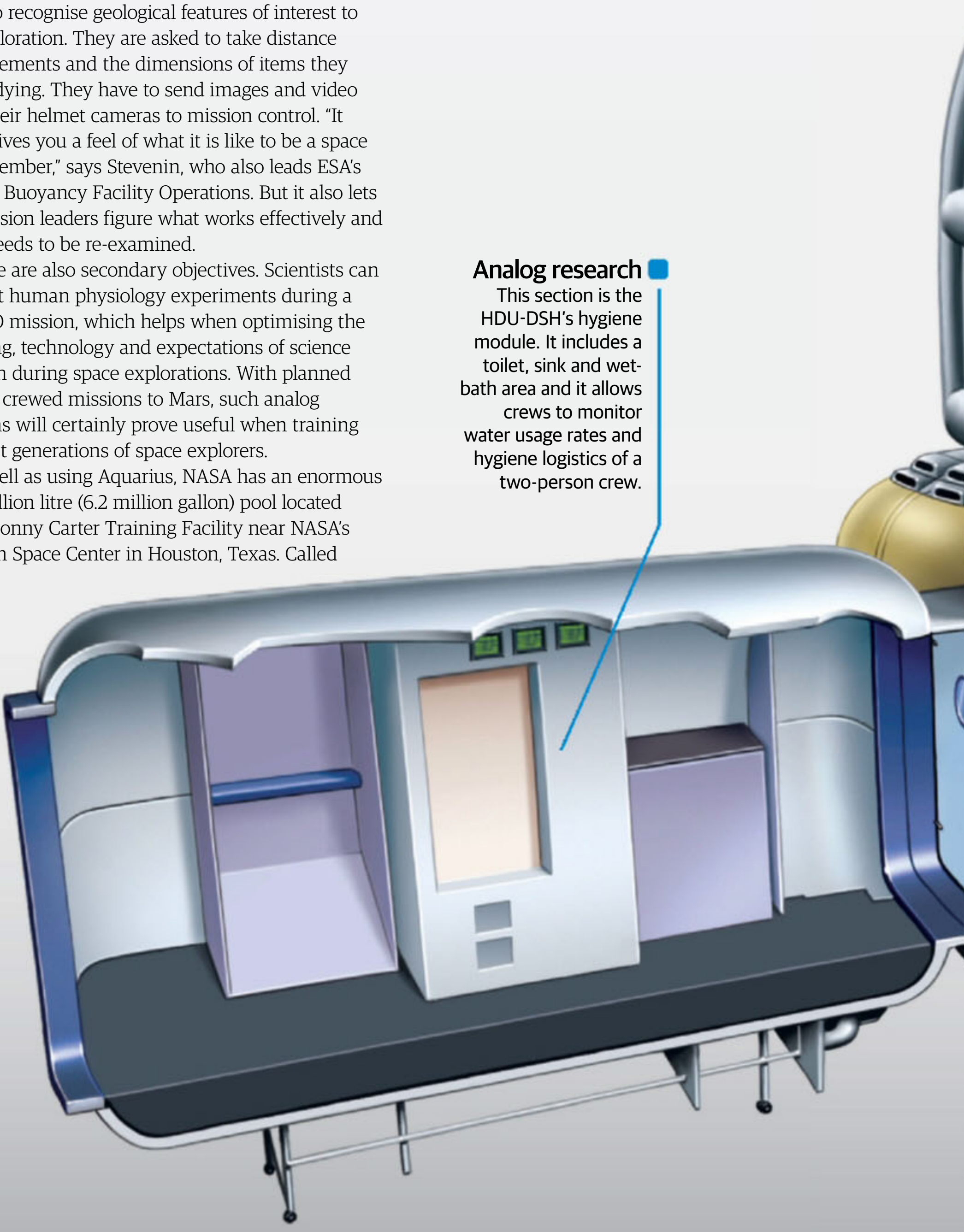
LB: CAVES is a good analog. If anything, it can be even worse in a cave; more isolating than on a space station. Communication is achieved by a wire up to the base camp but if you just twist an ankle or a wrist you have to be carried out. You have to pay attention to everything you do because you only have the very limited visibility given by your headlamp. It's just like on an EVA where astronauts have limited visibility through their helmet. You can get disorientated so it is very important to have situational awareness at all times.



CAVES exposes astronauts to isolation, confinement and difficult communication, all of which are typical in space flight

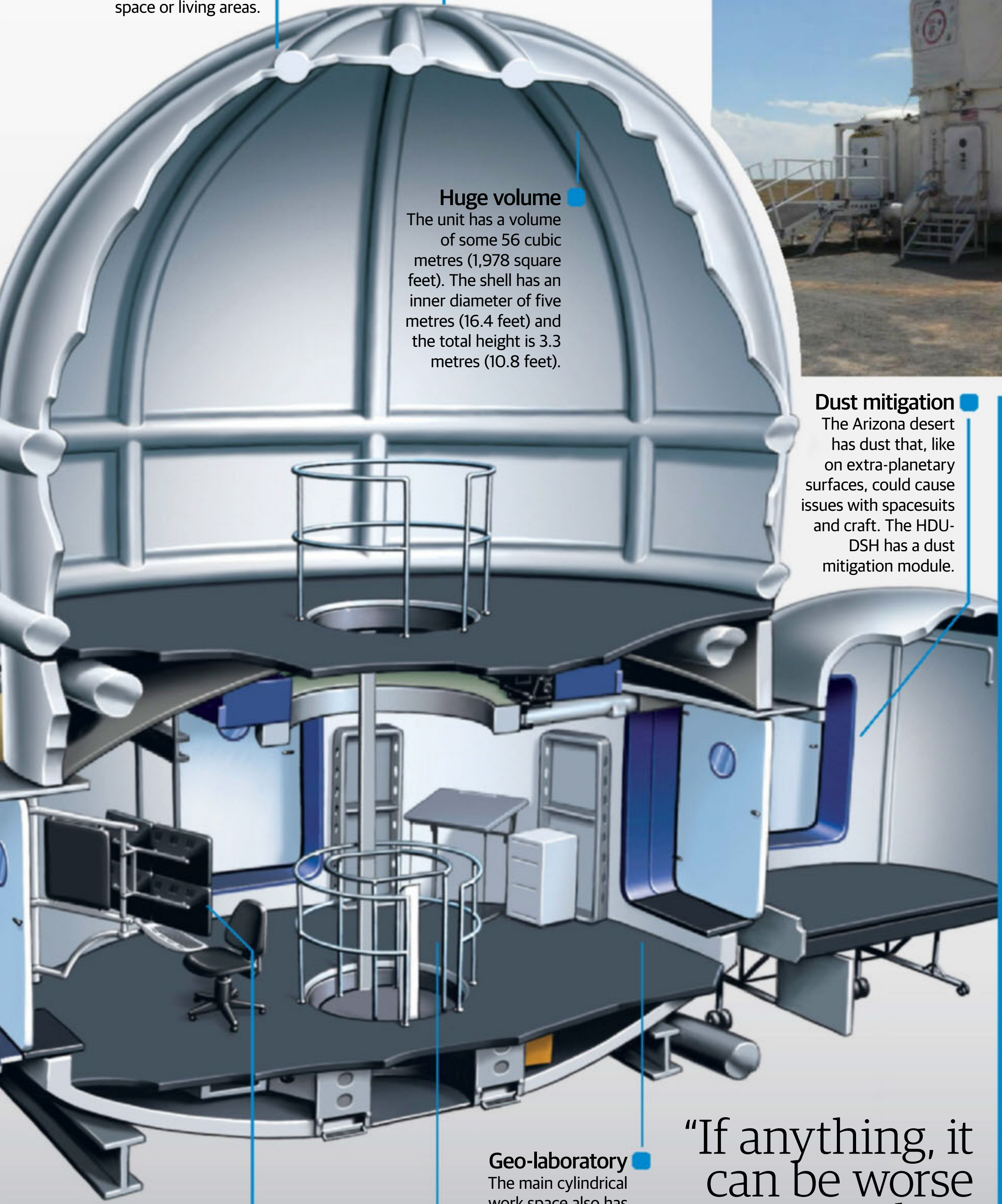
The Deep Space Habitat

Analog research from Desert RATS (Desert Research and Technology Studies) enables NASA architects, engineers and scientists to create the perfect space base



Analog research

This section is the HDU-DSH's hygiene module. It includes a toilet, sink and wet-bath area and it allows crews to monitor water usage rates and hygiene logistics of a two-person crew.



The shell
The shell of the Habitat Demonstration Unit – Deep Space Habitat (HDU-DSH) has space for an inflatable loft. This allows the astronauts to create additional laboratory space or living areas.

Material make-up
The prototype unit shell is made of composite fibreglass resin. It is attached to eight steel ribs, each of which is just 0.8 centimetres (0.3 inches inches) thick.

Huge volume
The unit has a volume of some 56 cubic metres (1,978 square feet). The shell has an inner diameter of five metres (16.4 feet) and the total height is 3.3 metres (10.8 feet).

Dust mitigation
The Arizona desert has dust that, like on extra-planetary surfaces, could cause issues with spacesuits and craft. The HDU-DSH has a dust mitigation module.

Work space
Since the HDU-DSH is an operational base, it allows astronauts to process geological samples or perform scientific experiments.

A lift
To enable astronauts to move up to the second level, there is a lift in the centre of the unit.

Geo-laboratory
The main cylindrical work space also has a geo-lab, a general maintenance workstation and medical operations. The space is broken into clearly defined segments.

Desert RATS helps prepare astronauts for carrying out tasks and experiments on Mars, the Moon and asteroids

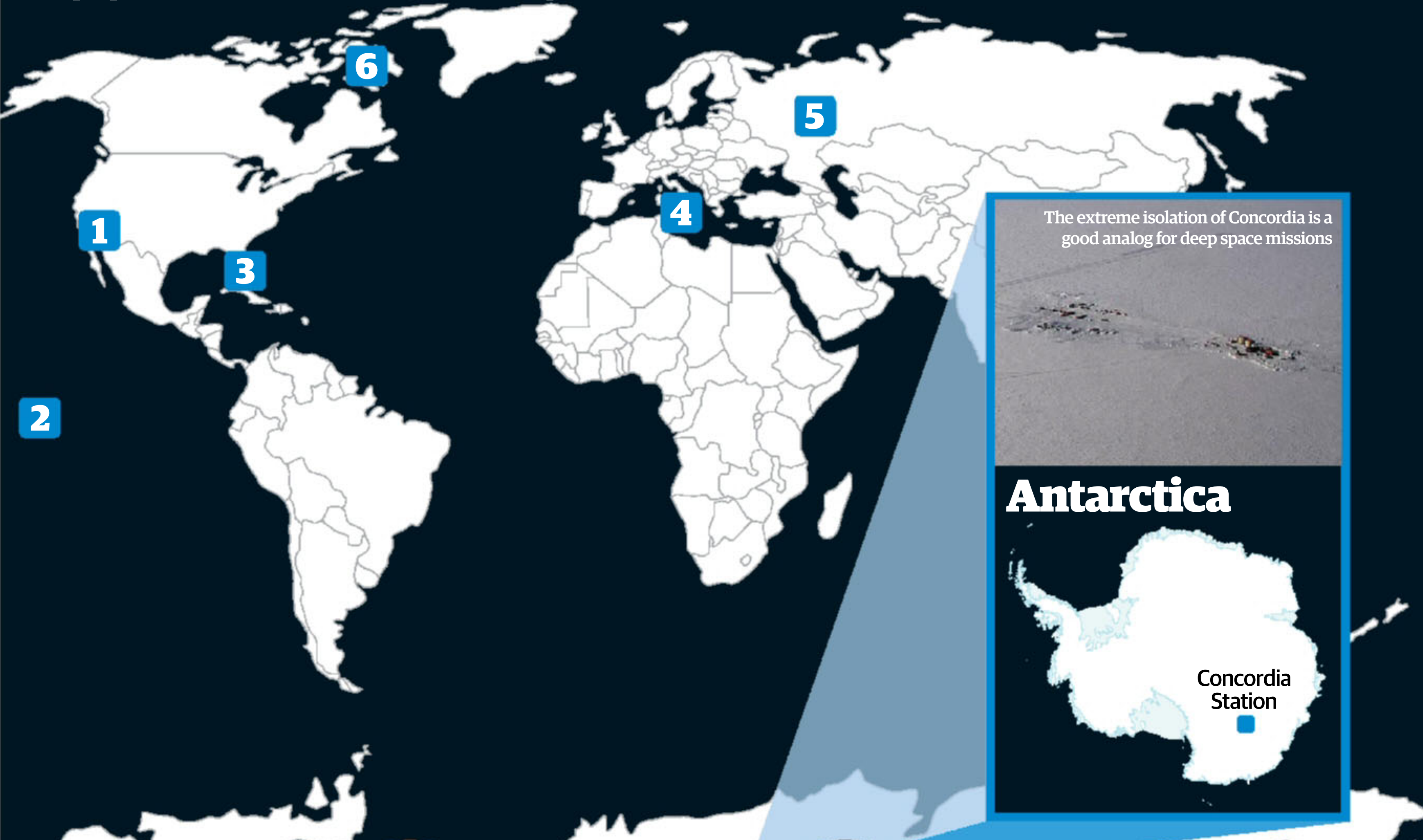
> "If anything, it can be worse in a cave than on a space station"
> **Loredana Bessone, CAVES mission director**

Desert RATS training

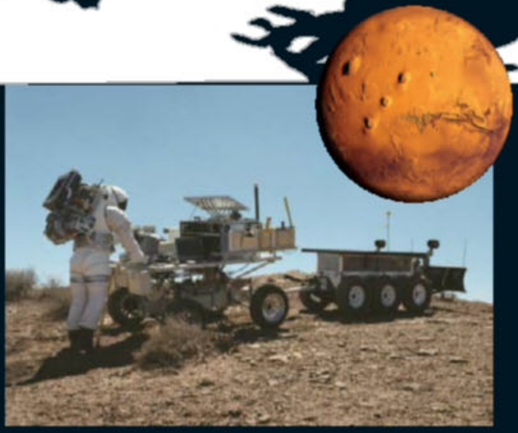
Located by a 2-million-year-old lava flow near Flagstaff, Arizona, Desert RATS conducts annual missions, with an emphasis on testing roving and spacewalks. They test for optimum crew sizes and the science that can be conducted on Mars, the Moon or other rocky bodies. It has experimented with backpacks and arm-mounted computers and it has introduced cutting edge robots. It has also experimented with surface networking and spacesuits that can use speech recognition to control suit parameters or the movement of robots. Any technology trialled one year is refined and tried again the next. The six-legged ATHLETE all-terrain vehicle has been chopped back to three legs, for example, and retested.

Where in the world?

The training facilities across the globe that prepare astronauts for extra-terrestrial expeditions



The extreme isolation of Concordia is a good analog for deep space missions



1. Desert RATS

Flagstaff, Arizona

Desert Research and Technology Studies (Desert RATS) makes use of the Black Point Lava Flow site in Arizona which shares a host of environmental and terrain similarities with Mars, the Moon and near-Earth asteroids. As well as understanding how rovers can cope with craters, slopes, dust storms and volcanic ash fields, it also looks at the tasks that would be better suited to humans such as sample collection.

2. In-Situ Resource Utilisation

Mauna Kea, Hawaii

When astronauts in the future land on the Moon, they would, ideally, be able to produce their own oxygen from lunar rocks and soil. This dormant volcano has proven to be a perfect simulation of the Moon's polar regions. Scientists have studied the effectiveness of rovers to produce oxygen in such a harsh, dusty environment. It's a complex process so it's vital to be able to test the systems here on Earth first.

3. NEEMO

Off the coast at Key Largo, Florida

Astronauts need to be prepared for a hostile, reduced-gravity environment and all of the risks that poses. NEEMO places six astronauts in isolation underwater. It assesses their physiology, psychology and nutrition and it teaches them the benefits of teamwork. Since the water constrains mobility, astronauts also get a good understanding of what an EVA on a planet or asteroid would be like.

4. CAVES

Sardinia, Italy

When astronauts perform EVAs on the International Space Station, they need to be able to operate while tethered and to carry out repairs, under pressure, in the dark and with limited visibility (as happened in December 2013 when a damaged cooling pump needed a repair). CAVES works on the leadership, decision-making, problem-solving and teamwork skills of cavenauts in isolated darkness.

5. Mars 500

Russian Academy of Sciences' Institute of Biomedical Problems, Moscow, Russia

To send a human crew to Mars will take a long journey of some 245 days each way. With a few people in a confined space, it's important to protect their mental and physical health. Mars 500 simulated a 520-day Mars mission, giving three volunteer crews between 2007 and 2011 the opportunity to live and work in a mocked-up spacecraft.

6. Haughton Mars Project

Devon Island, Nunavut, Arctic Canada

Smart rovers, in particular, are useful for scouting sites before humans arrive and for collecting surface geology data. The remote isolation of the Haughton crater research station can help with the exploration of a Martian environment. Its unpredictable terrain is perfect for testing rovers and for astronauts: they can practice changing into a spacesuit from a pressurised vehicle while avoiding dust from entering.

> "The astronauts have to do body checks, remain attached to ropes and work together with their teammates" **Loredana Bessone**

the Neutral Buoyancy Laboratory, it isn't a mission as such but a training exercise and yet it contains a mock-up of the International Space Station (ISS) modules and payloads and it allows for the simulation of weightlessness. Astronauts who intend to work on the ISS can familiarise themselves with the station's segments in an environment near identical to the real-life situation.

To simulate the weightless condition experienced during flight, astronauts need to maintain neutral buoyancy within the pool in order to avoid sinking or rising within the water. "This is the only way to experience weightlessness on the ground," says Stevenin. To do this, the astronaut's body must have an average density equal to the density of the fluid. It is achieved by adjusting the weight of the diving suit. By simulating microgravity and rehearsing spacewalks (or extra-vehicular activity (EVA) as they are known), the astronauts are able to experience some of the conditions they would experience when tending to the exterior of the ISS.

For the unimaginably cold temperature of space, the temperature at the Concordia Station in Antarctica can drop to -80 degrees Celsius (-112 degrees Fahrenheit). It is a useful analog for long duration deep space missions due to its confinement and extreme isolation. During the dark winters, the crew can be without hope of escape or deliveries for nine months. Scientists test for sleep disruption, telemedicine (medical advice via phone or internet), circadian rhythm and, thanks to the air pressure being equivalent to the top of Mount Fuji in Japan, chronic hypobaric hypoxia – a condition that arises from the body being deprived of sufficient oxygen.

As such, within each analog mission small advances are invariably made, allowing plans to be revised and retested, with each meticulous detail noted so that scientific observations are at their most productive. The In-Situ Resource Utilisation (ISRU) analog mission in Mauna Kea, takes place at a dormant volcano in Hawaii, for instance. It has developed and tested mining equipment and production facilities to produce oxygen, fuel and water in-situ. The volcano helps to simulate the conditions of astronomical objects such as Mars and the Moon. It is hoped that, by introducing and examining new techniques, this analog mission will help reduce the amount of materials that need to be carried into space from Earth.

Analog missions are vital in this regard. Many of them put astronauts through challenging situations and by studying their behaviour and testing equipment or operational concepts, real-life missions can be refined for the benefit of the astronauts, research and productivity.

This is certainly true of ESA's CAVES (Cooperative Adventure for Valuing and Exercising human behaviour and performance Skills). It is a two-week course which teaches astronauts to explore the Sa Grutta caves in Sardinia, Italy. The emphasis is on astronauts working as a multicultural crew in a critical environment, re-creating spaceflight stressors while performing real scientific and exploration tasks.

Many of the procedures used underground are very similar to those on the ISS, with the same standards, formats and terminology. CAVES also trains astronauts to select samples and it assists them in the techniques of identifying the most important. For this reason, CAVES is quickly expanding, with the life science groups of NASA and ESA interested in conducting live science experiments that would accompany another major test site over at Pavilion Lake, British Columbia, Canada. This is a mission that not only lets astronauts assess microorganisms for their scientific value but allows for the testing of robot systems and pressurised underwater vehicles.

In fact, CAVES – which asks participants to live, work and explore in dark, cramped, isolated conditions deep underground – has been built as a combined environmental, scientific and operational analog to human space flight. "It's a very challenging analog mission especially because communication is only made available in selected locations with poor quality," says CAVES course and mission director Loredana Bessone. "The cavenauts cannot come back quickly to the surface either. It takes a few hours to reach the exit in nominal conditions."

For this reason cavenauts must use several techniques to develop situational awareness. They will very often stay close to the walls to orientate themselves. "The astronauts have to do body checks, remain attached to ropes and work together with their teammates," adds Bessone. "And it's a good analog, according to the participants who have been on the course and later flown in space flight. Many consider it to be one of the best if not the best analogs that they have ever been trained on."

Indeed, putting astronauts into such extreme environments can, as a consequence, help their development enormously. The Arizona-based mission Desert RATS (Desert Research and Technology Studies) simulates the operations of planetary exploration, exposing astronauts to the technologies and techniques that will protect them against the extreme environment of Mars or the Moon.

Desert RATS also looks at the possibility of humans one day occupying planets, moons and near-Earth asteroids. Habitats are trialled – the most recent being the HDU-DSH (Habitat Demonstration Unit – Deep Space Habitat) – that allow for crews to set up a longer-term base. Experiments are performed on these living and working quarters to ensure astronauts are comfortable, safe and able to carry out tasks while communicating with Earth-based crews.

Without the benefit of these kinds of analog missions – the likes of which have been conducted since the days of Apollo – space flight and exploration would be almost impossible. With them, astronauts, engineers and scientists are gaining new understanding, advancing science and coming up with new methods and technology. The future of human space exploration continues to look bright. ■

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5 AMAZING FACTS ABOUT

The Great Red Spot

The most recognisable feature on Jupiter might not be around for very much longer

© NASA

It's shrinking

Since the Thirties, when astronomers started recording the changes in its diameter, the Great Red Spot has dwindled in size. It was thought to be over 41,000 kilometres (25,500 miles) wide in the 19th Century and subsequent measurements of our space probes and telescopes have shown it to be shrinking by 933 kilometres (580 miles) per year to its current diameter of 16,500 kilometres (10,250 miles).

Sometimes it changes colour

In recent years it has changed colour, fading almost to the tinted cream clouds that frame it. The astronomer Thomas Gwyn Elger drew the spot as a deep tawny blob in his 1881 sketch, but the pasty image Voyager 1 took nearly a century later in 1979 looks hardly like the Great Red Spot at all.

No one knows what causes it

Whatever sustains the Great Red Spot is as big a mystery as its origin. For that reason, we don't know when or if it will disappear altogether. Some scientists think it might be gone by 2030, although others think it will hit a critical limit where it can maintain its size and even grow bigger again.

It's a giant hurricane

Jupiter's most famous feature has an average temperature of about -160 degrees Celsius (-256 degrees Fahrenheit) with a core several degrees warmer, enough to generate winds of up to 432 kilometres per hour (268 miles per hour), although the currents inside the spot are virtually stagnant.

It's over 300 years old

Since Jupiter's iconic Great Red Spot is an anticyclonic storm, it is not a permanent feature, but it's been raging since at least the early 17th Century. It was likely first observed by Giovanni Cassini in 1665, although its discovery is often credited to British scientist Robert Hooke.

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- **Constellations can be used for navigation.**
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Duke became the youngest person to walk on the Moon at the age of 36

Youngest man on the Moon

On 16 April 1972, Apollo 16 left Earth and headed to the Moon. The mission's Lunar Module pilot Charles Duke recounts the day his astronaut boot touched the lunar soil

Interviewed by Gemma Lavender

INTERVIEW BIOS

Charles Duke
As Lunar Module pilot for Apollo 16, Charles Duke became the tenth and youngest person to walk on the Moon at the age of 36, when he landed on its surface in 1972. An engineer, retired Air Force Officer and test pilot, Duke has spent over 260 hours in space.

Could you tell us a bit more about how you went about choosing the landing site without crashing?
There is no dark side of the Moon, it's actually the far side. Obviously it rotates once every 28 days. There are two weeks of daylight and two weeks of night on every spot of the lunar surface. Apollo 16 landed with a low Sun angle to give us [the Apollo 16 team consisted of Duke, commander John Young and Command Module pilot Ken Mattingly] definition of the lunar surface. If you tried to land at high noon, it was all washed out [by sunlight], which meant that you couldn't see any of the craters and you couldn't see any of the elevation changes. The landing site was therefore chosen at a very low Sun angle, so that we had all of the shadows to the West. It was early morning during the Moon day at the Apollo landing site, which was called Descartes. We got some definition of the landing site, which meant that we didn't crash or fall into a big crater.

The further east you go, the more the backside of the Moon was in darkness. We landed just a little east and a little south of the centre and could see that half of the backside of the Moon was in sunlight.

What did you see as you entered lunar orbit?
As we entered the shadowed portion of the Moon, you got this eerie feeling because the Sun hadn't been shining on this region for a few days. The feeling was so unreal that I was left thinking: 'well, I hope our tracking is right!'

You're going into orbit at 60 by 70 miles [97 by 113 kilometres] above the Moon. And so, we burned to slow down and manoeuvre into orbit. At this point, the computer told us that we were out of contact with the Earth and that we had loss of signal. Then, all of a sudden there was the sunrise, it was the most dramatic sunrise I've ever seen. In Earth orbit, you see the Sun's glow on the horizon or the planet's atmosphere and it gets brighter and brighter. The Moon is different though - there's instant sunlight with long shadows on the lunar surface. The far side of the Moon was very rough back there. I would not have wanted to land on the backside of the Moon.

The manoeuvre into orbit [when we were close enough to the Moon] lasted around two minutes and 41 seconds. During that time, we burned about 2 million kilograms [4.4 million pounds] of fuel. We took pictures of the Earth [from lunar orbit] after we left our planet over Australia around an hour after lift-off. Earth was like a jewel suspended in the blackness of space. The Sun shines all of the time on the way to the Moon but the stars are never visible. It's very dark when you look outside and all you see is the Earth, Moon and Sun.

Why didn't you land on the far side of the Moon?
We wanted to be in contact with the Earth, so we weren't able to land on the backside of the Moon. We ended up landing at a place called Descartes - our landing site was in the Descartes Highlands. We were the fifth mission to land on the Moon and I can say that it really is a dramatic place.

We had to lower the spacecraft further down into orbit by about 60 by eight miles [97 by 13 kilometres]. That would be the orbit in which we would attempt to land. At this point we needed a critical burn of the main engine because if you had one second overburn, you ended up impacting the Moon's surface. As we were lowering ourselves, we looked out of the window as we came around from the backside of the Moon to make sure that we weren't going to crash into its surface. If we felt like we were going to, then we would have had to bail out.

Your Command Module pilot Ken Mattingly was meant to go on a mission to the Moon before you, what happened?
[Laughs] Mattingly was supposed to be on Apollo 13,

The Apollo 16 Saturn V vehicle carrying the mission's astronauts

Duke is pictured here collecting lunar samples at the Descartes landing site

> "If the roving vehicle broke down then we would have had to walk back - there's no rescue on the Moon!"

The Apollo 16 crew. From left, Mattingly, Young and Duke

but I caught measles a week before the launch and exposed him to the measles, so they jerked him off the flight and we ended up on a flight together.

What was lift-off like?
Everybody went to the Moon on a Saturn V rocket. At lift-off the engines were producing 3.5 million kilograms [7.7 million pounds] of thrust, so you didn't lift off very fast but you were shaking like crazy from side to side. I got a little bit nervous, you don't see outside of Apollo at this point. The windows were covered over, so I got a little bit nervous and my heart was pounding. I said: "I hope this thing makes it" because the vibration was so intense.

Later on, when we returned to Earth, I spoke to the flight surgeon who was based at mission control and asked what my heart rate was. He said: "It was 144 beats per minute - you were excited!" and I replied: "You bet I was excited!" I then asked what John [Young]'s was and, apparently, his was 70. So he was the cool one.

What did you do as soon as you landed?
We were supposed to go outside right after we landed, but we didn't get the chance. Instead, we went to sleep and had a rest period. That was pretty hard to do, three hours after we landed on the Moon. With a sleeping pill though, I was able to do it.

Could you describe the moment you left the Lunar Module?
I opened the door, and got on my hands and knees and crawled out backwards down the ladder and onto the footpath. From the door to the footpath, to give you some idea, is about five metres [16 feet] in height. Descartes had some mountains and plains as well as a big valley, which was about ten kilometres [6.2 miles] wide. We would explore this valley over our three-day stay. You could see the shadows of the Sun, in the direction of Stone Mountain. The Sun was always in the west while we were on the surface.

We drove further afield on our second EVA [extra-vehicular activity]. It was about four kilometres [2.5 miles] from where we landed. We were actually going to go out as far as 100 kilometres [62 miles], but we didn't drive that far because if the roving vehicle broke down then we would have had to walk back - there was no rescue up on the Moon!

How did the Moon feel under foot?
The Moon is covered with this very fine dust, like a powder, which is actually pulverised rock. When we walked on it, we didn't sink any further than a couple of inches. One of the problems in the beginning was that some of the scientists thought that we were going to land in lunar dust that was 200 to 300 metres [656 to 984 feet] deep and we were going to sink when we stepped outside.

Did you get a chance to study the Moon's surface?
We could see the western horizon from our location. And we could see a place called North Ray crater and all of the white rocks in our area were from the meteor impact that made that crater. We collected three colours of rocks - grey ones, white ones and black ones. Lesson number one in geology is to

Duke as Apollo 11 CAPCOM in 1969

pick up a rock in every colour and so we were able to get the whole suite of Moon rocks. We collected about 98 kilograms [216 pounds] of lunar soil. We also had a whole suite of experiments. Two seismic experiments [to measure seismic waves through the Moon], a mass spectrometer [to figure out what the lunar soil and rocks are made of] and a heat flow experiment, which unfortunately failed. We also had two magnetometers [to measure the magnetic field].

To the west of where we landed was Plum Crater. It was about two metres [6.6 feet] deep – or perhaps a bit deeper. We gave it a wide berth because we didn't want to fall into it since, as I said earlier, there is no rescue on the Moon and we wouldn't be able to get out. We got a good view of the lunar surface during the mission, we got plenty of samples and a good view of the lunar colours – there were different shades of grey. We collected rocks with different shovels, rakes and tongs.

We could see for a long way from Stone Mountain which is the furthest we got on the mission and the lunar plains glistened in the sunlight. It was very bright on the Moon, so we had our visors down at all times. In some places, our footprints were barely there because the lunar soil was so thin. I drilled three holes in the Moon – around three metres [9.8 feet] deep – and the soil was still quite solid. In some areas on the lunar surface, it was like walking on a solid floor. There was no dust at all.

What did the Earth look like from the Moon?

From where we stood on the Moon, the Earth was directly overhead. And it stays there. I did see the Earth from lunar orbit, but not from the Moon. If you look up, you're looking at the top of your helmet – this part of your spacesuit doesn't move back with your head. I only ever saw the Earth when I fell backwards one time – it scared me half to death! I fell back, and said: "Oh, yeah, there it is!" It's a good job that I knew how to get back up again because I would still be on the Moon.

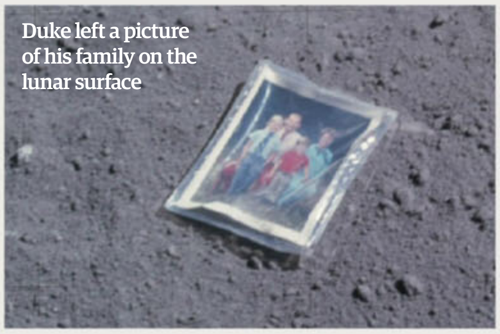
Apollo 11's Neil Armstrong and Buzz Aldrin left a flag on the Moon. Did you leave your mark in a similar way?

I left a picture of my family on the Moon. People wondered why I did that but I really wanted to get my family involved in the mission. We were travelling and training all of the time [so I rarely got to see my family] and so I asked them: "Would you like to be on the Moon with me?" My children said: "Yes, sir, we sure would!"

So we took this picture of the family and on the back of the picture, we wrote: "This is the family of astronaut Duke from Planet Earth. Landed on the Moon, April 1972". We all signed the picture. It's still there. The lunar rover is still there also and we left the TV camera running on the front of it. The rover could travel at a maximum speed of 17 kilometres per hour [10.6 miles per hour]. Up on the Moon, which only has 17 per cent of the Earth's gravity, it felt like you were flying.

On your return to Earth, where did you land?

We splashed down in the Pacific Ocean and the three parachutes started to open before fully deploying as we landed in the water. It was one of the most beautiful sights I ever saw [laughs]. We were grateful for the parachutes – without them, the spacecraft would have hit the water with such force that Apollo 16 would have split open and we would have sunk to the bottom of the ocean.



Duke left a picture of his family on the lunar surface

A view of the Earth from Apollo 16

Commander John Young (pictured here with the lunar rover) was also a crew member of Apollo 16

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The Antares explosion

What exactly happened when a recent ISS resupply mission exploded mid-launch?

On 28 October this year, an Orbital Sciences Corporation Antares rocket exploded in an enormous fireball just seconds after launch. Luckily, the rocket was an unmanned resupply mission destined for the International Space Station. So, despite the loss of 2,268 kilograms (5,000 pounds) of station supplies and science experiments (plus, no doubt, some of the ISS astronauts' favourite snacks), no one was hurt. But what went wrong, exactly?

The investigation into the explosion concluded that one of the two main engines on the Antares rocket failed shortly after the countdown finished. As a result, Orbital Sciences, who was contracted by NASA to make the delivery to the ISS, had to trigger a shutdown - a self destruct on the rocket - for safety reasons. Orbital Sciences will no longer use the engine model, and Roscosmos sent replacement cargo up to the ISS shortly after.

The aftermath of the explosion at the Wallops Island launch facility, taken on the day following the failed mission

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YOUR QUESTIONS ANSWERED BY OUR EXPERTS

In proud association with the National Space Centre
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Sophie Allan

National Space Academy education officer
■ Sophie studied Astrophysics at university. She has a special interest in astrobiology and planetary science.

Zoe Baily

National Space Centre
■ Zoe holds a master's degree in Interdisciplinary Science and loves the topic of space as it unites all the different disciplines under one topic.

Josh Barker

Education team presenter
■ Having earned a master's in Physics and Astrophysics, Josh continues to pursue his interest in space at the National Space Centre.

Gemma Lavender

Senior staff writer
■ Gemma has been elected as a fellow of the Royal Astronomical Society. She is a keen stargazer and telescope enthusiast on **All About Space** magazine.

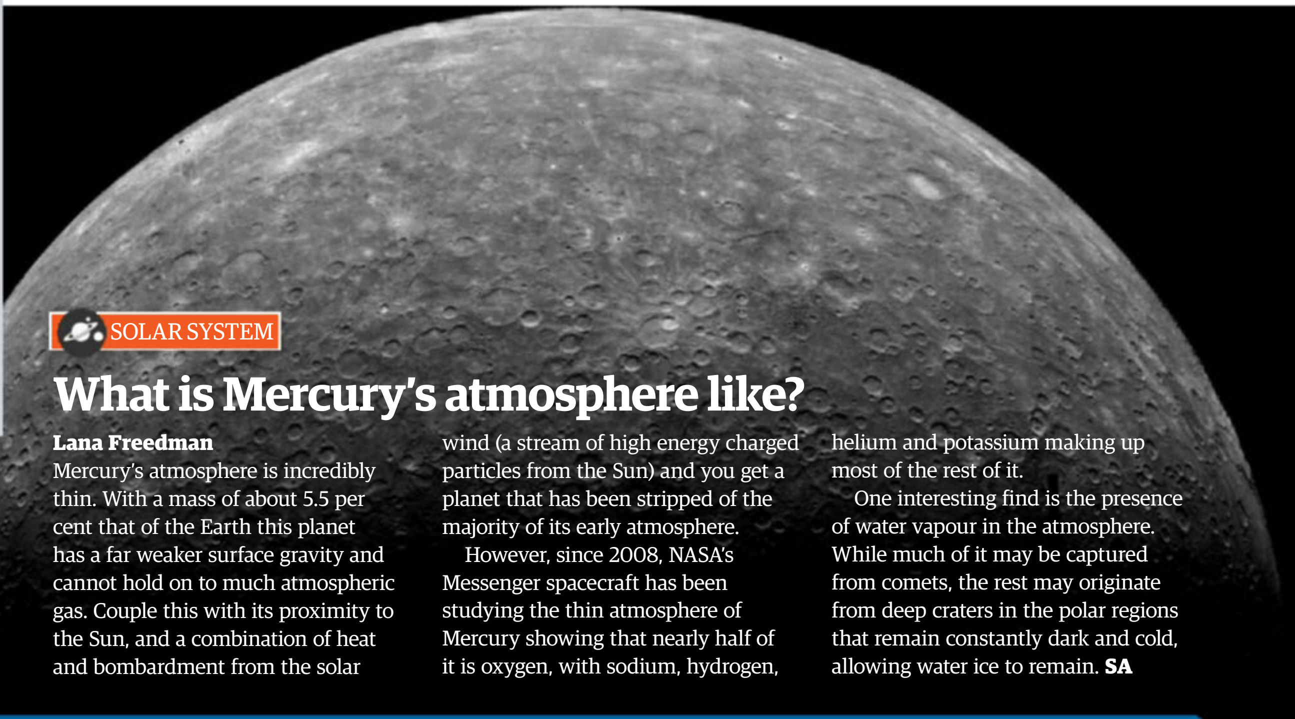
DEEP SPACE

Can we find planets at the centre of a galaxy?

Ben Lankton

In theory, there is nothing stopping planets being formed in the centre of a galaxy but, in practice, their formation is quite tricky since the core of these giants are violent places.

It's thought the centre of the majority of galaxies contain a supermassive black hole. This results in some radical dynamics. Evidence of protoplanetary discs has been found in our own Milky Way but often any encounter with the chaos that occurs at its centre results in these discs being shredded. So, while unlikely, there is always a chance that one has been lucky and found an island of stability within the maelstrom. **JB**



Mercury has an incredibly thin atmosphere

SOLAR SYSTEM

What is Mercury's atmosphere like?

Lana Freedman

Mercury's atmosphere is incredibly thin. With a mass of about 5.5 per cent that of the Earth this planet has a far weaker surface gravity and cannot hold on to much atmospheric gas. Couple this with its proximity to the Sun, and a combination of heat and bombardment from the solar wind (a stream of high energy charged particles from the Sun) and you get a planet that has been stripped of the majority of its early atmosphere.

However, since 2008, NASA's Messenger spacecraft has been studying the thin atmosphere of Mercury showing that nearly half of it is oxygen, with sodium, hydrogen, helium and potassium making up most of the rest of it.

One interesting find is the presence of water vapour in the atmosphere. While much of it may be captured from comets, the rest may originate from deep craters in the polar regions that remain constantly dark and cold, allowing water ice to remain. **SA**

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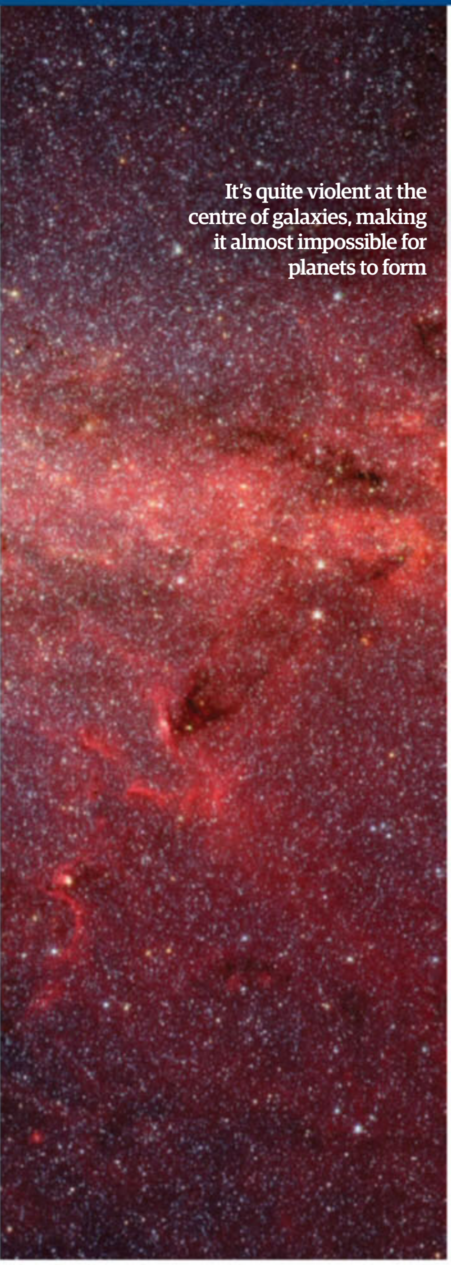


It's quite violent at the centre of galaxies, making it almost impossible for planets to form

SPACE EXPLORATION

Could Philae have changed Comet 67P's orbit when it landed?

John Garnet

Philae - the robotic lander of the European Space Agency's Rosetta probe - was dropped on to Comet 67P/Churyumov-Gerasimenko in November. However, the manoeuvre hasn't changed the orbit of the comet.

There are two reasons why this is not possible. The first is that when Rosetta entered into orbit around the comet in August 2014, the pair became gravitationally bound. The comet lost a little bit of angular momentum - the amount of rotation that it had - to Rosetta and if the comet were to be perturbed at all, it would have happened at this point. Second, Rosetta is 1,230 kilograms (2,712 pounds) while Philae is a mere 100 kilograms (220 pounds). Compared to the comet, which has a mass of ten billion tons, they are very light and unable to knock the comet out of its stride. **GL**

Brown dwarfs are neither planet nor star

DEEP SPACE

Are brown dwarfs more like stars or planets?

Dave Richardson

Although brown dwarfs have some similarities to both planets and stars they don't quite fit either category. They're believed to form through the same process as other stars, made when gas and dust coalesce, but without the mass to sustain prolonged hydrogen fusion at the core. After formation, these objects are too small to be considered a star (we refer to them in terms of Jupiter masses, not solar masses) and have a surface temperature less than 2,500 degrees Celsius (4,532 degrees Fahrenheit). They fit somewhere between our current definitions of stars and planets suggesting that perhaps these two classes are not as clear cut as we first thought. **ZB**

ASTRONOMY

What does it mean when we say a telescope is 'fast' in astrophotography?

Gerry White

The speed of a telescope refers to how much light it can gather and is a term that comes from photography. A lens with a high speed gathers much more light, meaning that the shutter speed can be faster in dim light improving those images. The speed of a lens is often referred to as an f-number and is calculated using a combination of the aperture (the lens diameter) and the focal length. It is worth noting, however, that these numbers and differences only really apply in photography. If the telescope is just being used for viewing with an eyepiece, with no astrophotography, the differences won't present themselves. **JB**

Speed takes on a new meaning in astrophotography

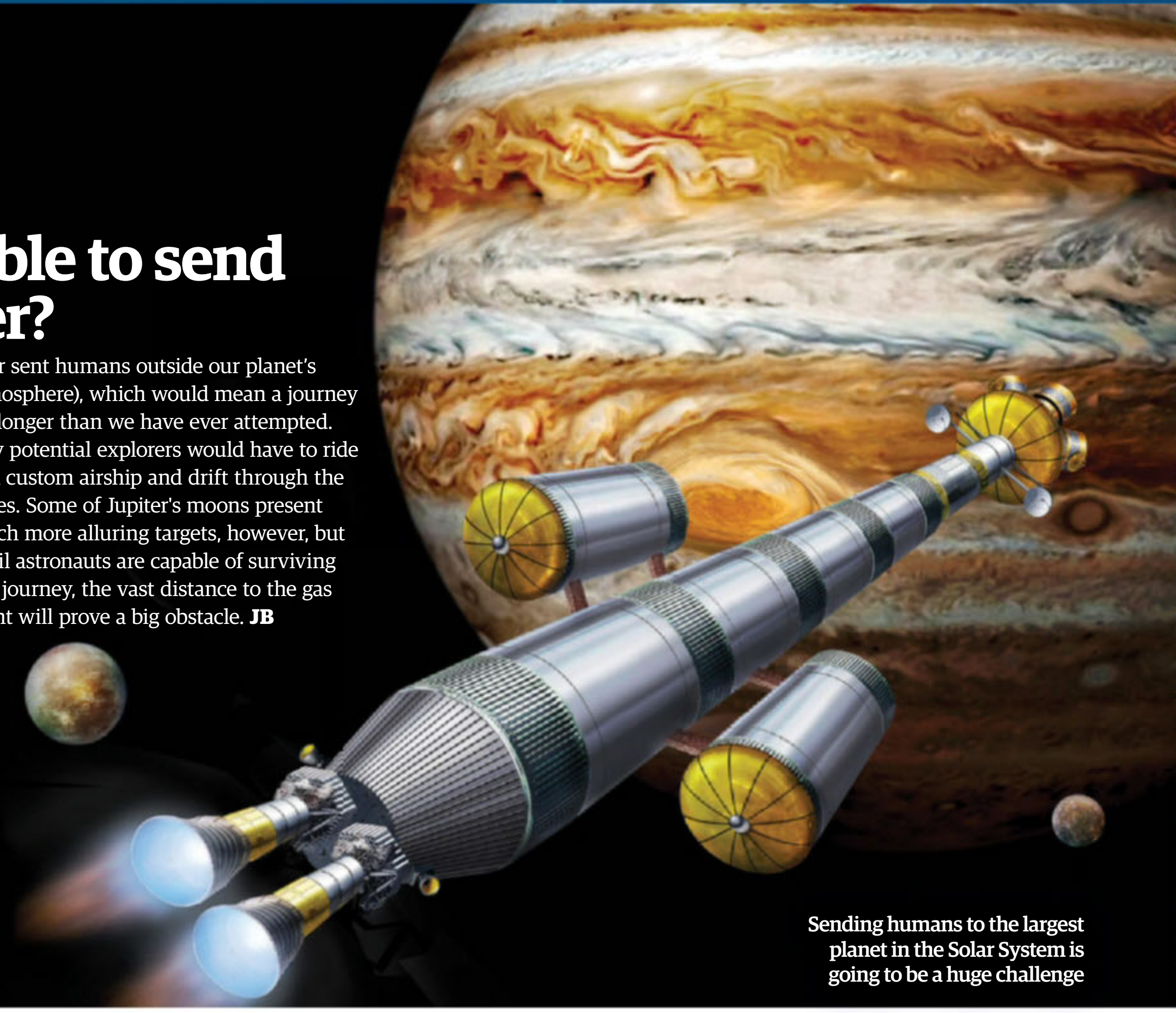
SPACE EXPLORATION

Will we ever be able to send humans to Jupiter?

Adam Kirkham

Jupiter is not only a long way from the Earth, it also doesn't have a solid surface for us to land on. This means that a crewed mission to the largest planet in the Solar System has not even entered the realms of consideration.

On average Jupiter is 1,500 to 2,500 times further away from the Earth than the Moon is (the furthest we have ever sent humans outside our planet's atmosphere), which would mean a journey far longer than we have ever attempted. Any potential explorers would have to ride in a custom airship and drift through the gases. Some of Jupiter's moons present much more alluring targets, however, but until astronauts are capable of surviving the journey, the vast distance to the gas giant will prove a big obstacle. **JB**



Sending humans to the largest planet in the Solar System is going to be a huge challenge

ASTRONOMY

Is it possible to see an exoplanet with my telescope?

Jane Hunt

Yes, and no. The only telescopes to have directly imaged exoplanets so far have been the biggest telescopes in the world, such as the ten-metre Keck telescopes in Hawaii, and the Hubble Space Telescope.

Most exoplanets are either detected by how they impart a wobble in their star, or by moving in front of their stellar parent and blocking some of its light, in what is called a transit. With a telescope with a ten-inch aperture or larger and a CCD that is able to monitor the light of a star, which has a planet in orbit around it, it is possible for an amateur observer to detect the light curve - a dip in light made by the transit. One amateur, Rolf Olsen, has even managed to image the dusty planet-forming disc around the star Beta Pictoris with a ten-inch Newtonian telescope. **GL**

Large telescopes, such as the ten-metre Keck telescopes in Hawaii, are able to find exoplanets much more easily than an amateur telescope

DEEP SPACE

What is the difference between a globular cluster and an open cluster?

Jack Bannister

Both are types of star clusters, but the major differences come down to the age of the stars found within them, where they can be found in a galaxy and their shape.

As their name suggests, globular clusters are globule-shaped balls of hundreds of thousands of stars all crammed into an area a few hundred light years across. They live in the halo of our galaxy and orbit the galactic centre. They are very old, at 12 to 13 billion years, while a few form the cores of smaller galaxies that have been cannibalised by the Milky Way.

On the other hand, open star clusters live in the spiral arms of the galaxy and are very young - the youngest are just several million years old, while the oldest can reach a few billion years old. The stars form together in a cluster inside a nebula and, as they age, they gradually disperse. **GL**

The Pleiades are the most famous open cluster

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You don't need a telescope to capture a star trail image

ASTRONOMY

How do I photograph star trails?

David Miles

You need to use a DSLR camera, affixed to a tripod. Remember though, as the Earth rotates the stars all seem to move around the Celestial North Pole (CNP), meaning that you would need to use exposures of several hours. The good news is that you don't need a telescope.

If you were to draw a line through the Earth, along its rotational axis, and extended it out into space, the part of the night sky it points to above the northern hemisphere is the CNP. It is marked by the Pole Star, also known as Polaris - the star that you should be pointing your camera at. The further a star is away from the Pole Star in the night sky, the wider the arc of its movement across the sky.

Your finished image will show how the light of the stars has trailed as they have moved across the sky - some more than others. But notice that one star - Polaris - doesn't move at all. **GL**

SOLAR SYSTEM

Why doesn't our Solar System have a hot Jupiter?

Jonathan Rosewall

Hot Jupiters are heated gas giant planets that are very close to their stars, just a few million miles distant and orbiting their stellar hosts in just a few days. The reason why there isn't one in our Solar System is down to its formation.

All gas giants form far from their star but then some migrate inwards. When they move closer, they push all the smaller planets in front of them either into the star or fling them out of the planetary system entirely. Planetary migration hinges on how thick the disc of gas and dust is and which planets are built. A thick disc will cause a planet to move closer to its star, while with a thinner disc, migration stops. Other planets in the system can also have an effect on a planet's orbit.

In the case of our Solar System, its dust disc dissipated before Jupiter had the chance to move very far - thankfully! **GL**

Our Solar System doesn't have an exotic hot Jupiter planet

Quick-fire questions

@spaceanswers

How fast does the Earth move around the Sun?

Earth completes its 940-million-kilometre (584-million-mile)-long circuit around our Sun each year (8,766 hours) at a speed of just over 100,000 kilometres (62,000 miles) per hour.

What is a white hole?

White holes are purely hypothetical and turn up in the mathematics of space-time around a black hole. If they did exist though, they are said to be the reverse of a black hole - that is, they spit things out rather than pull things in.

How far is Proxima Centauri from us?

The nearest star to our Sun, the red dwarf Proxima Centauri is around 4.2 light years away. That translates to around 40 trillion kilometres (25 trillion miles).

Can dark energy be affected by black holes?

Black holes have strong gravity but dark energy isn't affected by this force and so, in turn, it is not affected by black holes. Dark energy works in such a way that the universe expands.

What class of spiral galaxy is the Milky Way?

The Milky Way is a spiral galaxy. Many astronomers believe that it has a bar lacing through its centre, earning it the classification of a barred spiral galaxy.

What are the stars in Orion's Belt called?

The name of the three stars in Orion's Belt are Alnitak, Alnilam and Mintaka. They're also called Zeta Orionis, Epsilon Orionis and Delta Orionis, respectively.

What is the temperature on Europa?

The average temperature on Jupiter's moon Europa is approximately -160 degrees Celsius (-260 degrees Fahrenheit).

Quick-fire questions

@spaceanswers

Why do some solar eclipses take longer than others?

How long an eclipse takes depends on whether it's a partial or total eclipse, with the latter taking longer. It also depends on the distance between the Earth and Moon. When the Moon is closer to the Earth, it moves faster, ending the eclipse sooner.

How can I find out the moonrise times for my location?

You can find this information out from many guides and websites dedicated to astronomy. The Old Farmer's Almanac is a particularly good resource.

Is the Herschel Space Observatory still working?

Herschel ceased functioning when the space observatory ran out of coolant in April 2013. The mission lasted for three years, 11 months and 15 days.

What is the visible universe?

It is the portion of the universe that we can see using current technology. Mathematical models suggest the entire universe is at least 250 times bigger than this.

Could Earth get sucked into a black hole at the centre of our galaxy?

Many picture the centre of our galaxy as a great vacuum cleaner but it's not unless we get close to a black hole's event horizon - the point of no return - that you can get sucked in. Our stable orbit means this can never happen.

What was there before the Big Bang?

It's widely believed that time and space both started at the Big Bang, so it's thought that nothing existed before our universe.

Rockets are propelled in the same way as a balloon that has been blown up and let go

SPACE EXPLORATION

How do rockets work?

Terri Davies

Rockets work a lot like letting go of a balloon. Imagine you have just inflated a balloon, and are pinching the end so that it is closed. The stretched rubber is exerting a force on the air molecules inside, forcing them to be at a higher pressure than the air outside. When you let go, these air molecules are forced out, allowing the balloon to get to the same pressure outside and propelling it. In the same way, a rocket engine uses fuel to cause combustion, creating a product of hot gases that get forced out of the back of the rocket and propelling it in a similar fashion to a balloon. And, while one molecule in the reaction will only exert a small force, the effect of billions of combustion products leads to a large thrust force for the rocket. **SA**

Black holes have extremely powerful gravitational attraction

DEEP SPACE

Is it possible to go inside a black hole and survive?

Anne-Marie Bancroft

Most likely not. Black holes, whether they have the mass of one star or a million stars, have a very strong gravitational pull that increases enormously the closer you get to them.

This pull would create powerful tidal forces that would stretch you until they pulled you apart in a messy process called spaghettification. However, the more massive the black hole, the weaker its gravity - so for the biggest black holes in the universe the tidal forces might not be so great as to rip you apart. That is, at least not until you reach the singularity at the heart of one of these objects.

However, time will appear to slow down for you as seen from observers on the outside and once you are past the event horizon - the point of no return - there is no way that anything, not even light, can escape the black hole. **GL**

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The night sky hasn't changed very much compared to thousands of years ago

ASTRONOMY

How did the night sky look thousands of years ago?

Shaun Howes

The night sky many thousands of years ago would have looked similar to the one that you will see tonight. Many of the official constellations we use nowadays were first named by ancient civilisations such as the Greeks. The motion of the stars over time can result in changes in star patterns, but these motions are often so small that over just a few thousand years constellations will remain relatively unchanged.

Perhaps the most notable change would have been the change in the Pole Star - Polaris - the star that the constellations appear to circle around during the night (see 'How do I photograph star trails' on page 71).

From approximately 4000 BC to 1800 BC the Pole Star would have been a star called Thuban - which is located in the constellation Draco (The Dragon) - as opposed to the current North Star in Ursa Minor (The Little Bear). **ZB**

There's likely to be many chunks of space rock in our Solar System, which we haven't discovered yet

SOLAR SYSTEM

Are there any celestial bodies in our Solar System that we haven't discovered yet?

Pam Abel

Yes, we suspect there are still many unknown asteroids, comets and maybe even dwarf planets out there for us to discover. Celestial bodies whose orbits come close to the Earth are referred to as near-Earth objects (NEOs) and although more than 10,000 of these have been discovered and catalogued so far, it's believed that this is only a small percentage of the total out there.

Further out in our Solar System, towards the Kuiper belt and Oort cloud, it's thought that there are trillions of pieces of icy, space debris. Although many of these will be tiny, there may be larger bodies out there yet to be spotted. In fact, the discovery of the Pluto-sized celestial body Eris in 2005 contributed to the decision to redefine what a planet is. This ultimately led to the reclassification of Pluto as a dwarf planet alongside Eris and a number of other celestial bodies. **ZB**

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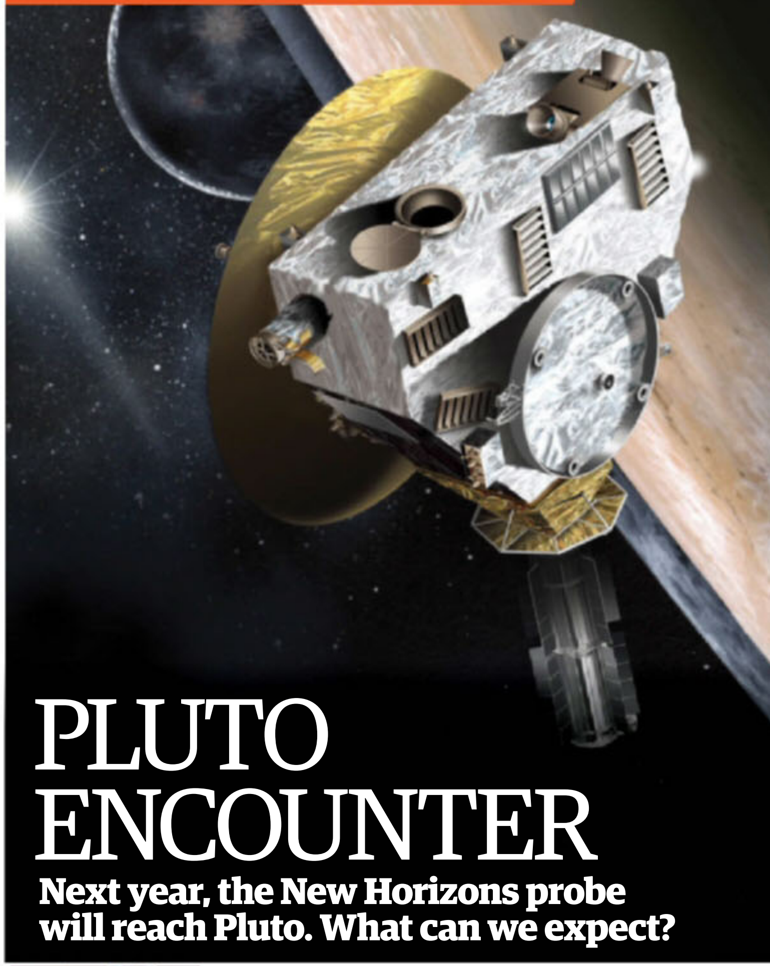
Next Issue

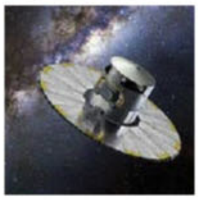


PLUTO ENCOUNTER

Next year, the New Horizons probe will reach Pluto. What can we expect?

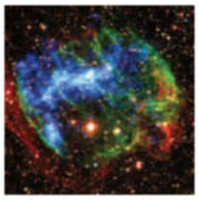
SPACE COLONIES

The science and tech behind our future expansion into space



HOW TO MAP A BILLION STARS

See how the Gaia telescope will create a 3D map of the Milky Way



10 COSMIC RECORD BREAKERS

From the biggest known supernova to the coldest place in space

+

WHITE DWARFS
THE COMET HITCH-HIKER
X-RAY SPACE TELESCOPE
DO WE LIVE IN A MULTIVERSE?
HOW TO SEE THE NORTHERN LIGHTS
STARGAZE WITHOUT A TELESCOPE

In orbit 8 Jan 2015

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The best stargazing sights of 2015

From the best time to see Saturn to a total solar eclipse, **All About Space** has your 2015 sky diary covered

JANUARY

2nd
M41 at its best

Object: open star cluster
Constellation: Canis Major
Right Ascension: 06h 46m 50s
Declination: -20° 43'
Magnitude: +4.6
Minimum optical aid: 10x50 binoculars

4th
The Quadrantids

Radiant: between Taurus and Gemini
ZHR: 80-120 per hour

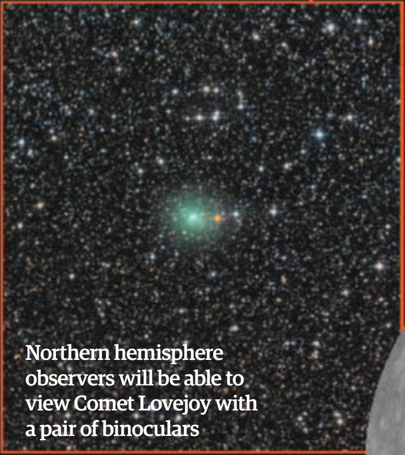
The Quadrantids are the first meteor shower of the year, displaying anywhere between 80 to 120 meteors per hour at the peak zenithal hourly rate (ZHR) and appearing to originate from the border between the constellations of Taurus and Gemini on 4 January. Sadly, this intense but short-lived meteor shower will be competing with light pollution from a nearly full Moon, meaning that many of the fainter meteors will be washed out to leave only the brightest.

8th
Conjunction between the Moon and Jupiter

Constellation: Leo

10th
Lovejoy hits maximum brightness

Comet C/2014 Q2 (Lovejoy) is predicted to reach a brightness of around magnitude +4.6 and will be visible all night for northern hemisphere-based observers after dusk above the southeastern horizon. It will be viewable using a pair of 10x50 binoculars until 1am before sinking below the western horizon.



Northern hemisphere observers will be able to view Comet Lovejoy with a pair of binoculars

14th
Mercury is visible in the evening

Constellation: Capricornus
Right Ascension: 21h 02m 50s
Declination: -17° 21'
Magnitude: -2.6

This is the first time Mercury ventures from the Sun in 2015, as the first planet from the Sun reaches greatest elongation east. At such a point in its orbit, Mercury is well placed for observation and shines brightly at magnitude -2.6 in the evening sky.

Being east of the Sun means that the planet sets a short time after sunset. Mercury will make its appearance after dusk.

30th

Asteroid 3 Juno at opposition

Object: asteroid
Constellation: Hydra
Right Ascension: 08h 31m 20s
Declination: +03° 47'
Magnitude: +7.8
Minimum optical aid: Medium-sized telescope

31st

Beehive Cluster (M44) at its best

Object: open star cluster
Constellation: Cancer
Right Ascension: 08h 40m 00s
Declination: -19° 58'
Magnitude: +3.7
Minimum optical aid: 10x50 binoculars

15th

M47 at its best

Object: open star cluster
Constellation: Puppis
Right Ascension: 07h 36m 30s
Declination: -14° 30'
Magnitude: +4.5
Minimum optical aid: 10x50 binoculars

16th

Conjunction between the Moon and Saturn

Constellation: Libra

23rd

Conjunction between the Moon and Mars

Constellation: Aquarius

FEBRUARY

6th

Jupiter at opposition

Constellation: Cancer
Right Ascension: 09h 20m 40s
Declination: -16° 31'
Magnitude: -2.6

The biggest planet in the Solar System, Jupiter will be at its most brilliant around 6 February when it reaches opposition - the point at which the planet is directly opposite the Sun and when this gas giant and the Earth are at their closest. Jupiter will be unmissable and brighter than any star or planet other than Venus as it dazzles at magnitude -2.6. At its highest at around midnight, when it is around 55 degrees above the southern horizon, the planet is a choice target for 10x50 binoculars where you will be able to see its moons. Using a small to medium-sized telescope will show you the planet's belts and zones and possibly the Great Red Spot under favourable conditions.

STARGAZER

MARCH

4th

Total lunar eclipse

Visible from: eastern Australia, America and Asia

Unless you're a resident of Australia, America or Asia, then you sadly won't be able to see the Earth's shadow fall across the lunar disc. If you are lucky enough to live in these parts of the world, then you'll see the Moon develop a crimson red hue, which many will agree is an eerie sight.

12th

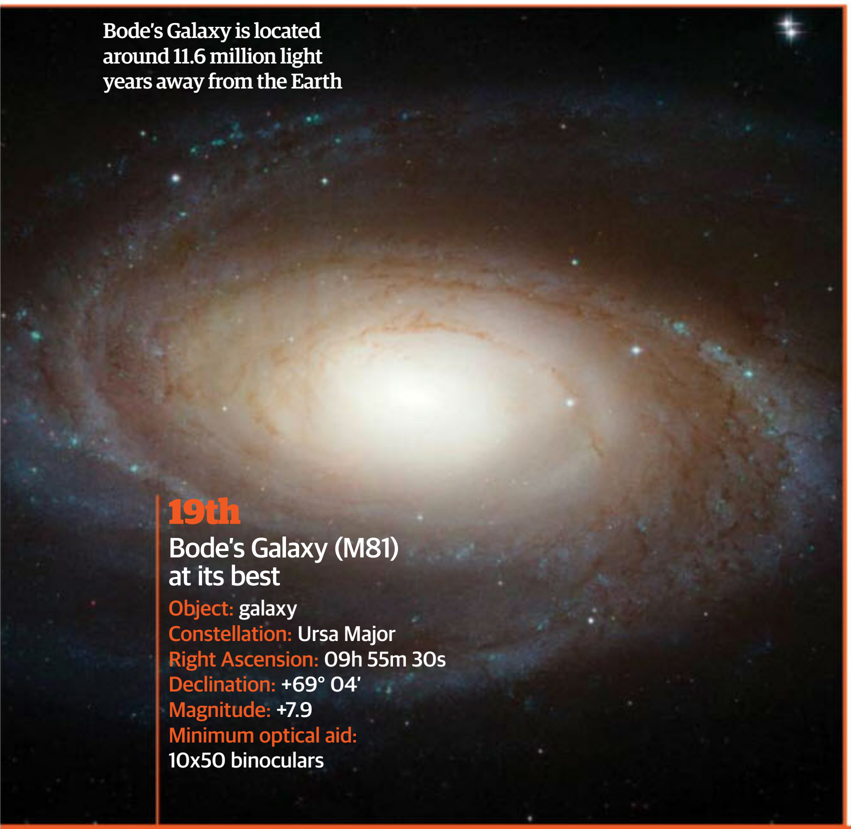
Conjunction between the Moon and Saturn

Constellation: Scorpius

13th

Conjunction between the Moon and Saturn

Constellation: Scorpius



Bode's Galaxy is located around 11.6 million light years away from the Earth

19th

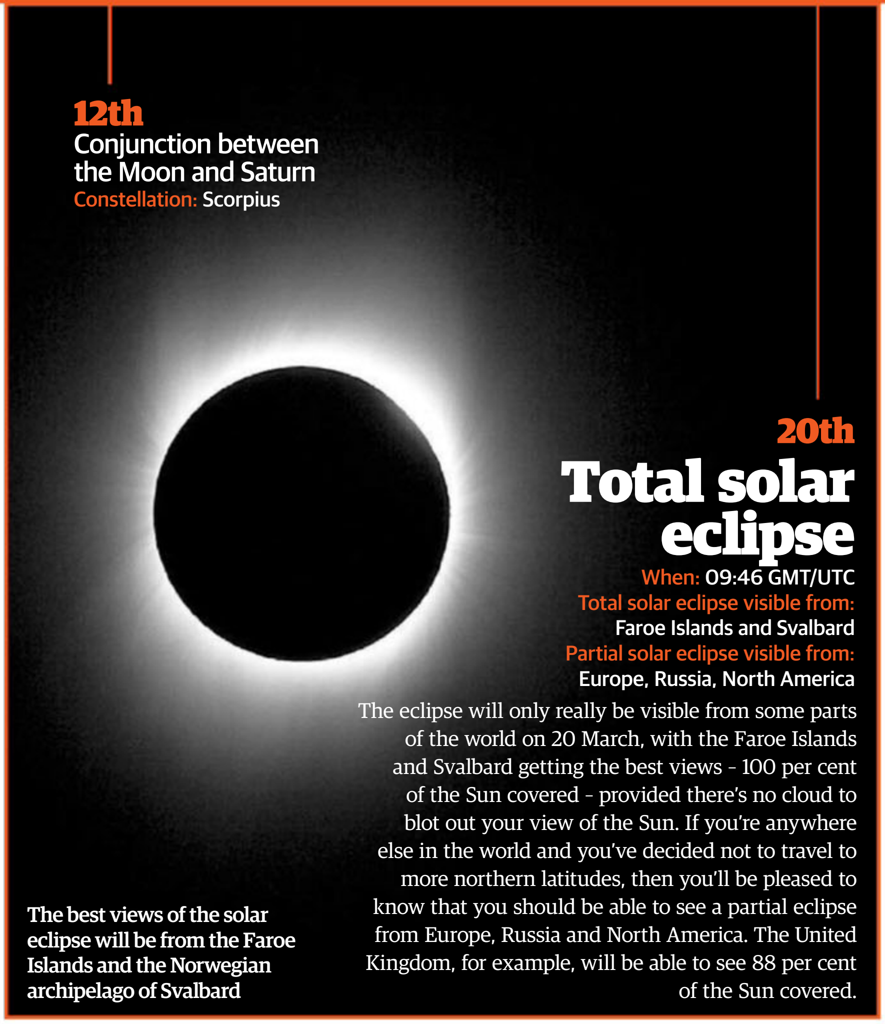
Bode's Galaxy (M81) at its best

Object: galaxy
Constellation: Ursa Major
Right Ascension: 09h 55m 30s
Declination: +69° 04'
Magnitude: +7.9
Minimum optical aid: 10x50 binoculars

20th

March equinox

Day and night have equal length, marking the beginning of spring in the northern hemisphere and the start of autumn in the southern hemisphere.



The best views of the solar eclipse will be from the Faroe Islands and the Norwegian archipelago of Svalbard

20th

Total solar eclipse

When: 09:46 GMT/UTC
Total solar eclipse visible from: Faroe Islands and Svalbard
Partial solar eclipse visible from: Europe, Russia, North America

The eclipse will only really be visible from some parts of the world on 20 March, with the Faroe Islands and Svalbard getting the best views - 100 per cent of the Sun covered - provided there's no cloud to blot out your view of the Sun. If you're anywhere else in the world and you've decided not to travel to more northern latitudes, then you'll be pleased to know that you should be able to see a partial eclipse from Europe, Russia and North America. The United Kingdom, for example, will be able to see 88 per cent of the Sun covered.

24th

Mercury is visible in the morning

Constellation: Capricornus
Right Ascension: 20h 44m 40s
Declination: -18° 05'
Magnitude: -1.9

Mercury will be well placed for observation in the dawn sky, unmistakably shining at a magnitude of -1.9, making it visible to the naked eye. However, the planet will be no higher than three degrees above the southeastern horizon and will rise 56 minutes before the Sun at around 6am.

APRIL

8th

Conjunction between the Moon and Saturn

Constellation: Scorpius

14th

Whirlpool Galaxy (M51)

Object: galaxy
Constellation: Canes Venatici
Right Ascension: 13h 29m 50s
Declination: +42° 12'
Magnitude: +9.0
Minimum optical aid: 10x50 binoculars

The Moon will turn a red colour during the total lunar eclipse on 4 April

17th

M3 is at its best

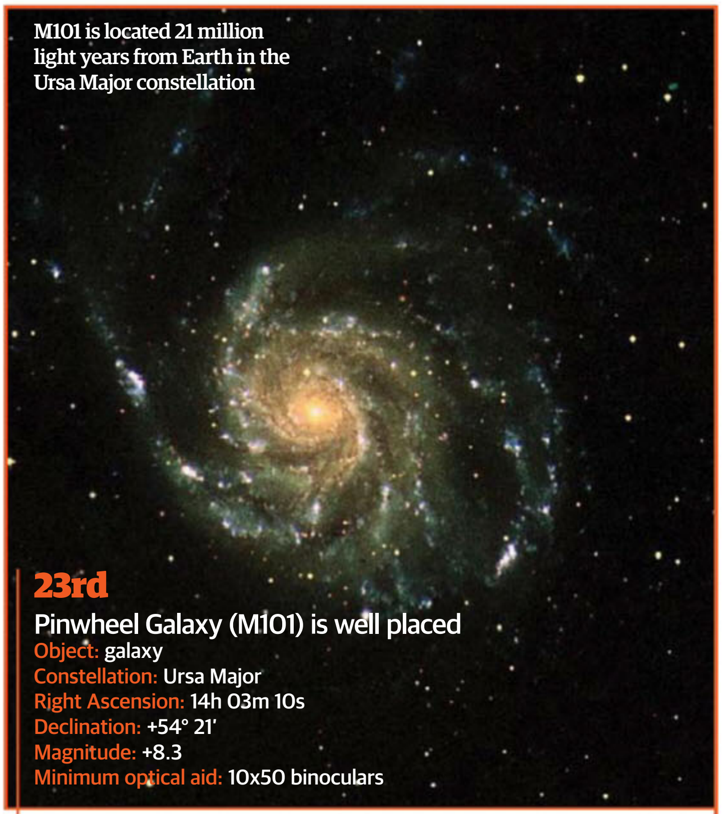
Object: globular cluster
Constellation: Canes Venatici
Right Ascension: 13h 42m 10s
Declination: +28° 22'
Magnitude: +6.2
Minimum optical aid: 10x50 binoculars

17th

The Lyrids

Radiant: Lyra
ZHR: 10 per hour

While the Lyrid meteor shower is relatively weak, a five-day-old Moon at peak activity on 23 April means that there will be minimal interference to wash them out. You will also see some odd shooting stars each night from around 19 April through to 25 April.



M101 is located 21 million light years from Earth in the Ursa Major constellation

23rd

Pinwheel Galaxy (M101) is well placed

Object: galaxy
Constellation: Ursa Major
Right Ascension: 14h 03m 10s
Declination: +54° 21'
Magnitude: +8.3
Minimum optical aid: 10x50 binoculars

MAY

16th

Observe the Southern Pinwheel Galaxy (M83)

Object: galaxy
Constellation: Hydra
Right Ascension: 13h 37m 00s
Declination: -29° 52'
Magnitude: +8.2
Minimum optical aid: 10x50 binoculars

M83 is one of the closest and brightest barred spiral galaxies to our own

6th

Eta Aquarids

Radiant: Aquarius
ZHR: 40 per hour

While random shooting stars will be visible each night from around 24 April through to 20 May, the peak of the Eta Aquarid meteor shower will reach its maximum rate on 6 May. Since the Moon will be 18 days old and therefore close to full, you might have a degree of difficulty in seeing the Eta Aquarids as the consequent light pollution limits observing the fainter meteors.

20th

Asteroid 532 Herculina is well placed

Object: asteroid
Constellation: N/A
Right Ascension: 15h 57m 10s
Declination: +01° 25'
Magnitude: +8.5
Minimum optical aid: Medium-sized telescope

12th

M5 is well placed

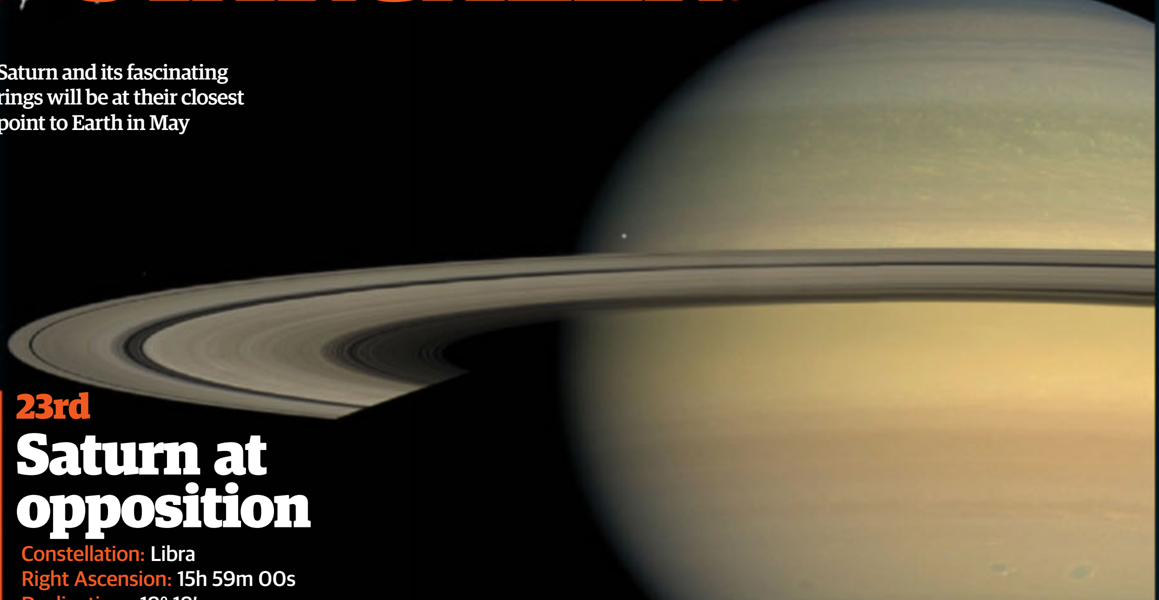
Object: globular cluster
Constellation: Serpens Caput
Right Ascension: 15h 18m 30s
Declination: +02° 04'
Magnitude: +5.7
Minimum optical aid: 10x50 binoculars

5th

Conjunction between the Moon and Saturn

Constellation: Scorpius

STARGAZER



Saturn and its fascinating rings will be at their closest point to Earth in May

23rd

Saturn at opposition

Constellation: Libra
Right Ascension: 15h 59m 00s
Declination: -18° 18'
Magnitude: +0.8

The warmer nights of May bring Saturn closer to us as it reaches a maximum magnitude of 0.8, resting in the constellation of Libra. Saturn will reach its highest point in the sky at around 1am on the evening of opposition where the ringed planet will be 20 degrees above your southern horizon. For a few hours around the moment of opposition, observers may be treated to a marked brightening in the gas giant's rings in comparison to its disc. A small telescope will also reveal the planet's largest moon, Titan, which shines at a magnitude of +8.0.

7th

Venus shines brightly in the evening

Constellation: Cancer
Right Ascension: 08h 15m 30s
Declination: +22° 18'
Magnitude: -5.0

Venus shines at a stunning magnitude of -5.0 when it makes its greatest elongation east in June. The second planet from the Sun will make its appearance at around 21:30 GMT above your western horizon as the dusk sky disappears.

Venus is stunning as a naked eye target, but telescope users might be disappointed. While they will be able to see the planet's phase, which will be a half-phase at greatest elongation, its appearance is quite bland - its thick cloudy atmosphere reflects a lot of light, which makes it so brilliant, but those same clouds also obscure any interesting features. Users of ultraviolet filters on their instrument can sometimes see a little more.

JUNE

28th

M4 is well placed

Object: globular cluster
Constellation: Scorpius
Right Ascension: 16h 23m 30s
Declination: -26° 31'
Magnitude: +5.6
Minimum optical aid: 10x50 binoculars

1st

Conjunction between the Moon and Saturn

Constellation: Libra

3rd

M12 is well placed

Object: globular cluster
Constellation: Ophiuchus
Right Ascension: 16h 47m 10s
Declination: -01° 56'
Magnitude: +6.7
Minimum optical aid: 10x50 binoculars

2nd

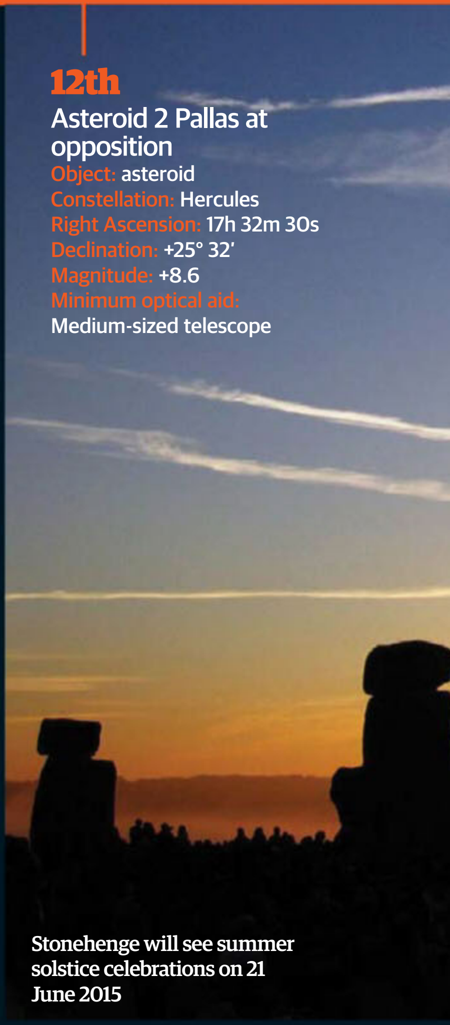
M13 is a great target

Object: globular cluster
Constellation: Hercules
Right Ascension: 16h 41m 40s
Declination: +36° 27'
Magnitude: +5.8
Minimum optical aid: 10x50 binoculars

12th

Asteroid 2 Pallas at opposition

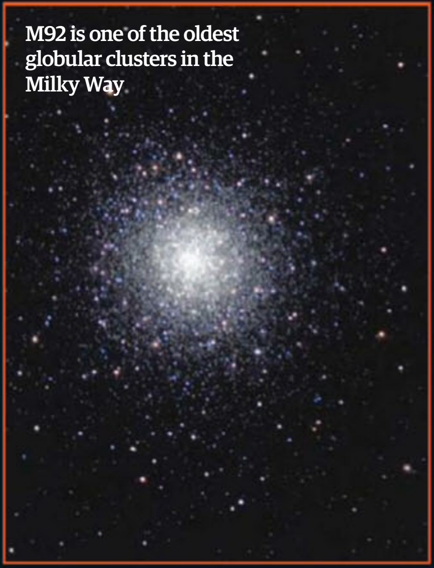
Object: asteroid
Constellation: Hercules
Right Ascension: 17h 32m 30s
Declination: +25° 32'
Magnitude: +8.6
Minimum optical aid: Medium-sized telescope



Stonehenge will see summer solstice celebrations on 21 June 2015

17th
M92 is at its best

Object: globular cluster
Constellation: Hercules
Right Ascension: 17h 17m 00s
Declination: +43° 08'
Magnitude: +6.4
Minimum optical aid: 10x50 binoculars



M92 is one of the oldest globular clusters in the Milky Way

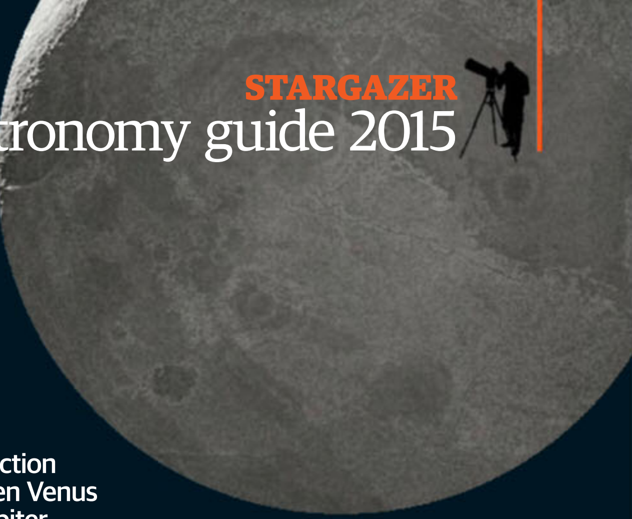
21st
June solstice

The June solstice marks midsummer in the northern hemisphere and midwinter in the southern hemisphere.

30th
Conjunction between the Moon and Jupiter

Constellation: Leo

JULY



1st
Conjunction between Venus and Jupiter

Constellation: Leo

6th
Pluto at opposition

Constellation: Sagittarius
Right Ascension: 19h 00m 00s
Declination: -20° 43'
Magnitude: +14.5

Very few have seen this tiny member of our Solar System since it is so small and faint - this makes it even more difficult to see as it moves against a very crowded backdrop of Milky Way stars. This year, Pluto is in the constellation of Sagittarius, which makes it all the more difficult to find. Being such a challenging object to observe, Pluto is best spotted by making sequential images of the region of sky the planet is moving through, over a period of three or four nights. If you compare the images, one 'star' would have moved a little bit - that's Pluto, barely shining at a magnitude of +14.5.

1st
M22 is well placed

Object: globular cluster
Constellation: Sagittarius
Right Ascension: 18h 36m 20s
Declination: -23° 54"
Magnitude: +5.1
Minimum optical aid: 10x50 binoculars

26th
Conjunction between the Moon and Saturn

Constellation: Libra

13th

Perseids

Radiant: Perseus
ZHR: 80 per hour

The Perseids will start to make their presence felt before they peak on 13 August as random shooting stars streak across the sky from 23 July all of the way through to 20 August. This particularly strong meteor shower promises a rate of 80 meteors per hour. Not only that, but with the Moon being 28 days old, there will be minimal interference to wash this shower out.

22nd

Conjunction between the Moon and Saturn

Constellation: Libra

28th

Supermoon

A supermoon occurs roughly after every 14 full Moons, when our lunar companion is at perigee in its orbit at the same time it is in the full phase. On 28 September, the Moon will be at its closest of the year as it comes within 356,896 kilometres (221,754 miles), presenting a larger-than-normal disc.

AUGUST

14th

M15 is at its best

Object: globular cluster
Constellation: Pegasus
Right Ascension: 21h 29m 50s
Declination: +12° 10''
Magnitude: +6.2
Minimum optical aid: 10x50 binoculars

15th

M2 is a great target for observers

Object: globular cluster
Constellation: Aquarius
Right Ascension: 21h 33m 20s
Declination: -00° 49'
Magnitude: +6.5
Minimum optical aid: 10x50 binoculars

SEPTEMBER

1st

Neptune at opposition

Constellation: Aquarius
Right Ascension: 22h 40m 30s
Declination: -09° 15'
Magnitude: +7.8

One of the toughest planets to see, ice giant Neptune will reach opposition at the beginning of September. Despite reaching opposition, Neptune is still roughly 28 times more distant from us than the Earth is from the Sun, meaning that you will need a large telescope to pick it out. Even then though, Neptune will still only appear as a star-like point.

If you are an astrophotographer, you can also use your skills to try to detect Neptune's largest moon, Triton, which is weakly visible at an even dimmer magnitude of +13.

13th

Partial solar eclipse

Visible from: Antarctica, Bouvet Island, French Southern Territories, Heard Islands & McDonald Islands and South Africa

19th

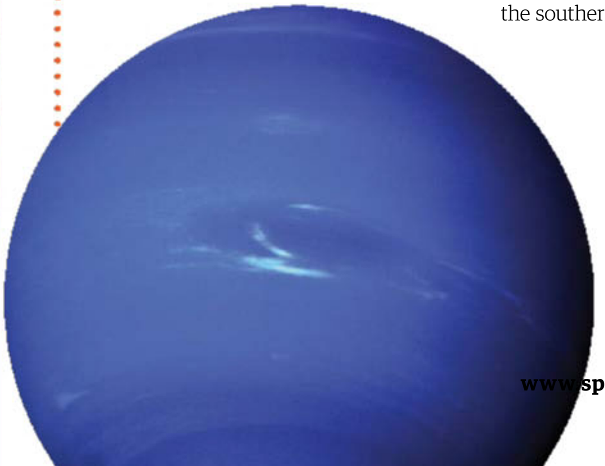
Conjunction between the Moon and Saturn

Constellation: Libra

23rd

September equinox

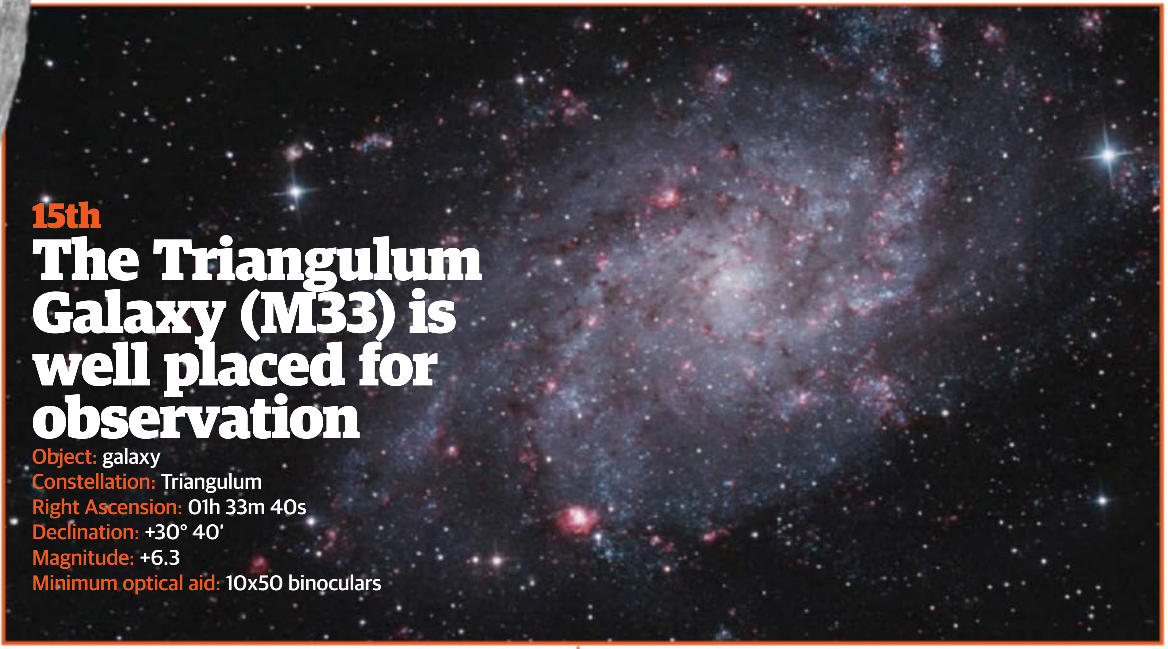
Day and night have equal length, marking the beginning of autumn in the northern hemisphere and the start of spring in the southern hemisphere.



28th

Total lunar eclipse

Visible from: Europe, Western Africa, Asia and USA



15th

The Triangulum Galaxy (M33) is well placed for observation

Object: galaxy
Constellation: Triangulum
Right Ascension: 01h 33m 40s
Declination: +30° 40'
Magnitude: +6.3
Minimum optical aid: 10x50 binoculars

2nd

M32 is well placed for observation

Object: galaxy
Constellation: Andromeda
Right Ascension: 00h 42m 40s
Declination: +40° 52'
Magnitude: +9.0
Minimum optical aid: 10x50 binoculars

8th

Conjunction between the Moon and Venus

Constellation: Leo

9th

Conjunction between the Moon and Mars

Constellation: Leo

16th

Conjunction between the Moon and Saturn

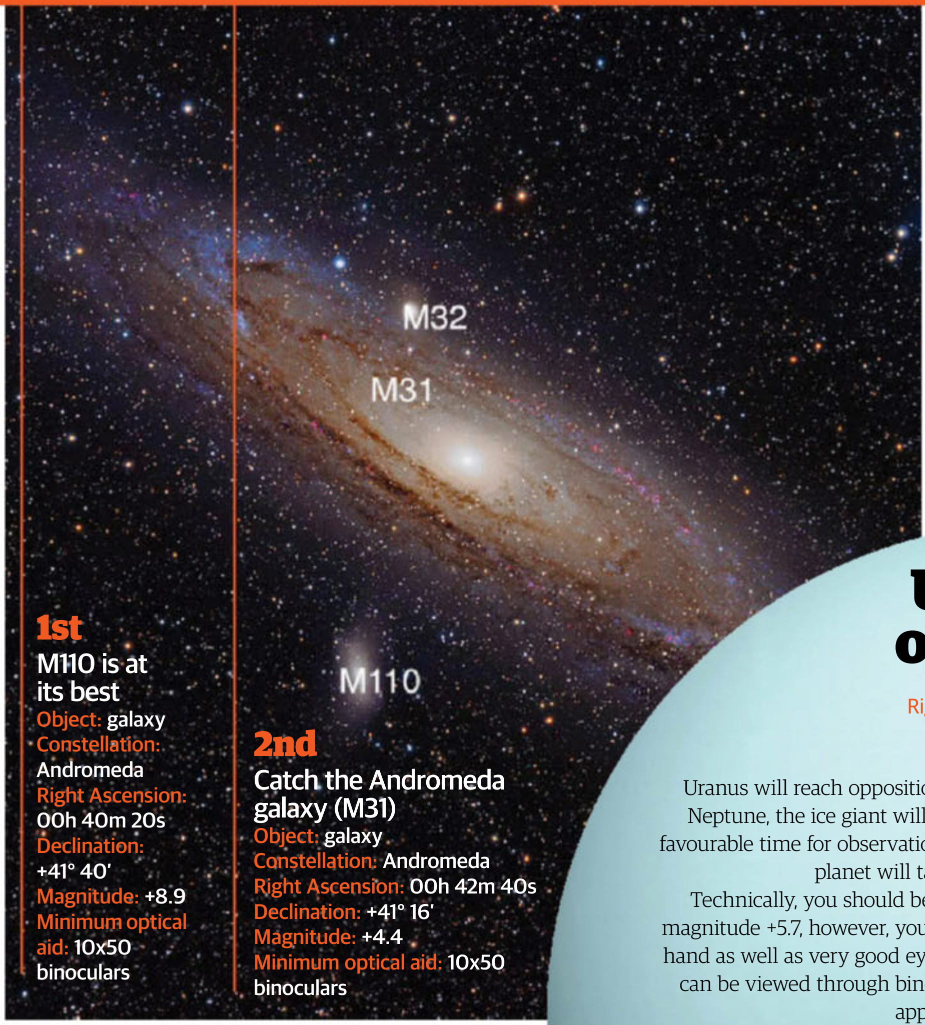
Constellation: Libra

25th

Conjunction between Venus and Jupiter

Constellation: Leo

OCTOBER



1st

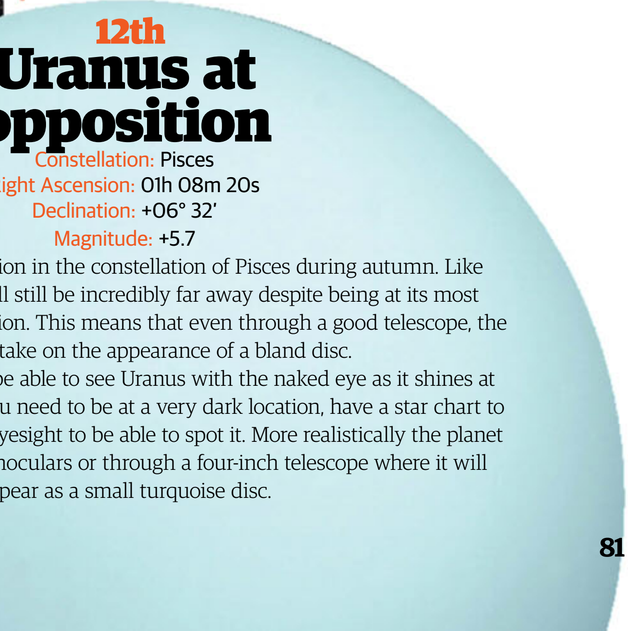
M110 is at its best

Object: galaxy
Constellation: Andromeda
Right Ascension: 00h 40m 20s
Declination: +41° 40'
Magnitude: +8.9
Minimum optical aid: 10x50 binoculars

2nd

Catch the Andromeda galaxy (M31)

Object: galaxy
Constellation: Andromeda
Right Ascension: 00h 42m 40s
Declination: +41° 16'
Magnitude: +4.4
Minimum optical aid: 10x50 binoculars



12th

Uranus at opposition

Constellation: Pisces
Right Ascension: 01h 08m 20s
Declination: +06° 32'
Magnitude: +5.7

Uranus will reach opposition in the constellation of Pisces during autumn. Like Neptune, the ice giant will still be incredibly far away despite being at its most favourable time for observation. This means that even through a good telescope, the planet will take on the appearance of a bland disc.

Technically, you should be able to see Uranus with the naked eye as it shines at magnitude +5.7, however, you need to be at a very dark location, have a star chart to hand as well as very good eyesight to be able to spot it. More realistically the planet can be viewed through binoculars or through a four-inch telescope where it will appear as a small turquoise disc.

16th

Mercury shines in the morning sky

Constellation: Virgo
Right Ascension: 12h 17m 40s
Declination: -00° 03'
Magnitude: -2.6
Minimum optical aid: naked eye

17th

Conjunction between Jupiter and Mars

Constellation: Leo

21st

Orionids

Radiant: Orion
ZHR: 25 per hour

With the Moon being eight days old, there will be significant interference for anyone wishing to observe the Orionid meteor shower in the early evening. Don't be disheartened though, it is possible to catch the brighter meteors streaking through the sky during the night.

18th

Observe the Pleiades (M45)

Object: open star cluster
Constellation: Taurus
Right Ascension: 03h 47m 30s
Declination: +24° 07'
Magnitude: +1.6
Minimum optical aid: naked eye

6th

Conjunction between the Moon and Jupiter

Constellation: Leo

20th

Asteroid 192 Nausikaa is well placed for observation

Object: asteroid
Constellation: Perseus
Right Ascension: 03h 27m 40s
Declination: +32° 46'
Magnitude: +8.4
Minimum optical aid: medium-sized telescope

14th

Geminids

Radiant: Gemini
ZHR: 100 per hour

The Geminids are the best meteor shower of the year, with roughly around 100 meteors per hour when they hit their peak on 14 December. A weaker meteor shower - the Ursids - will light up the skies just before Christmas with roughly ten meteors per hour between 17 and 25 December.

22nd

December solstice

The December solstice marks midwinter in the northern hemisphere and midsummer in the southern hemisphere.

NOVEMBER

3rd

Conjunction between Venus and Jupiter

Constellation: Virgo

7th

Conjunction between the Moon and Venus

Constellation: Virgo

7th

Conjunction between the Moon and Mars

Constellation: Leo

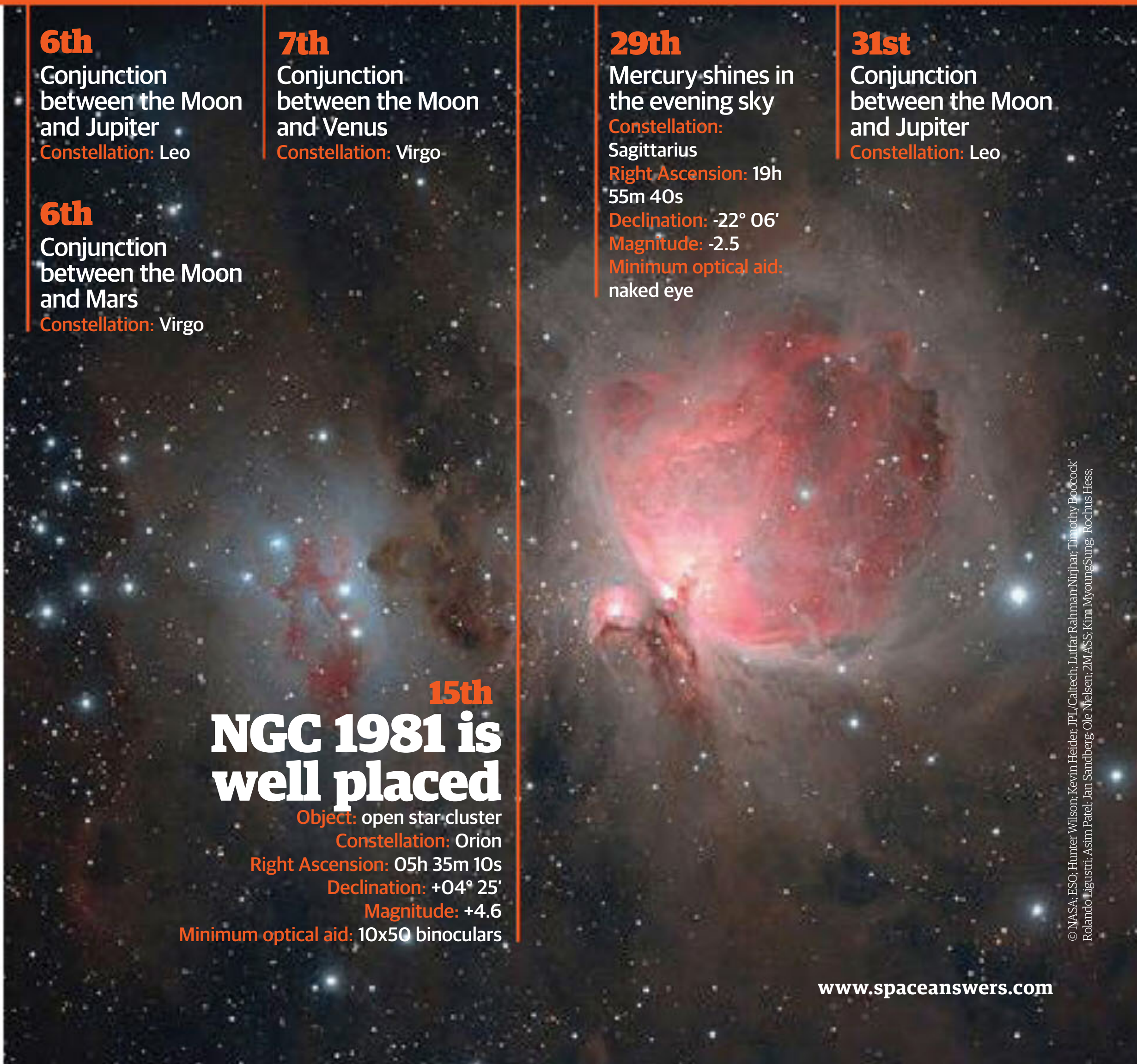
18th

Leonids

Radiant: Leo
ZHR: 20 per hour

The Leonids are expected to have a rate of 20 meteors per hour provided they are observed from a dark location. However, even if you are free from the pollution of city or town lights, the Moon still poses a problem since it is only seven days old. Despite this though, it is worth trying to catch stray Leonids around the shower's peak.

DECEMBER



6th

Conjunction between the Moon and Jupiter

Constellation: Leo

7th

Conjunction between the Moon and Venus

Constellation: Virgo

6th

Conjunction between the Moon and Mars

Constellation: Virgo

29th

Mercury shines in the evening sky

Constellation: Sagittarius
Right Ascension: 19h 55m 40s
Declination: -22° 06'
Magnitude: -2.5
Minimum optical aid: naked eye

31st

Conjunction between the Moon and Jupiter

Constellation: Leo

15th

NGC 1981 is well placed

Object: open star cluster
Constellation: Orion
Right Ascension: 05h 35m 10s
Declination: +04° 25'
Magnitude: +4.6
Minimum optical aid: 10x50 binoculars

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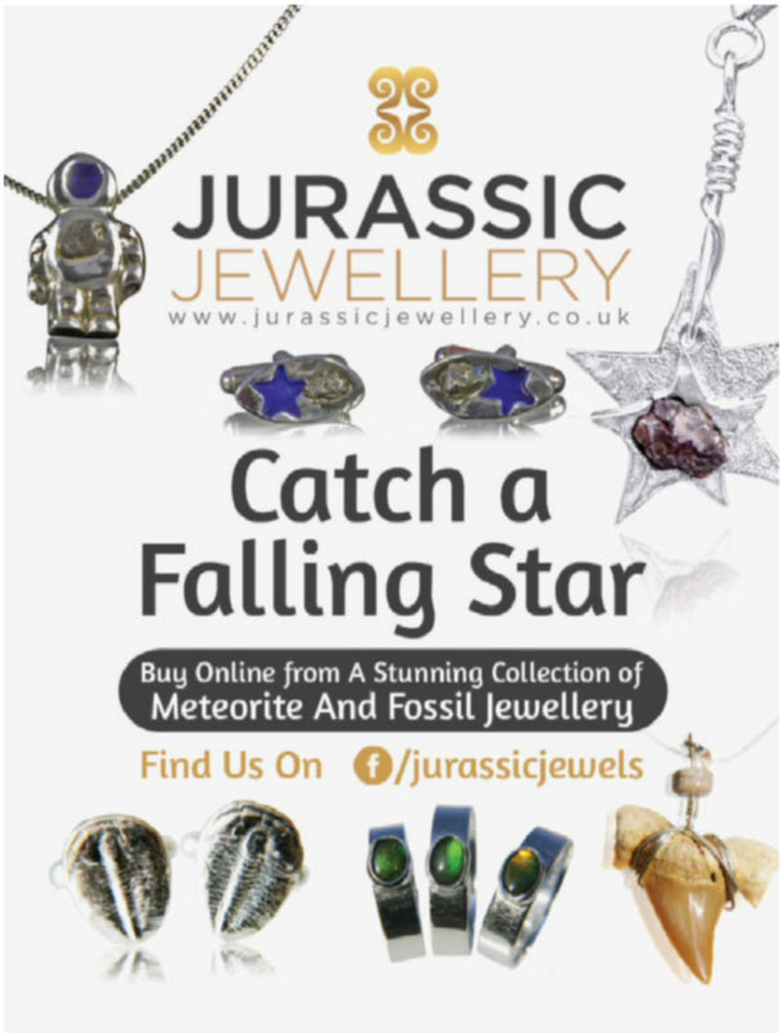

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What's wrong with my telescope?

Whether you've just cracked your brand-new telescope or you've been using your faithful instrument for years, there are some common problems you might find yourself faced with. Here's how to deal with them…

Problem

1. I can't see anything

It's not cloudy and you have ensured that your telescope's objective lens and finderscope caps are off, but you're still struggling to see your chosen target.

If you are having difficulty seeing anything through your telescope, then one or more of the following could be to blame.

Option 1

Your telescope might not be collimated properly

When a telescope is collimated properly all of its mirrors or lenses are aligned. When they are not lined up, then light from the object you're looking at can't be reflected or refracted in such a way that you can see the object through your eyepiece.

Solution

Schmidt-Cassegrain telescopes and reflectors can usually be collimated by yourself with ease, once you know what you're doing. However, unless you're an optical expert, we wouldn't advise trying to align the lenses in a refractor telescope. Remember, if you're unsure of how to collimate your instrument, it's best to err on the side of caution and take it to an expert who knows how.

Option 2

You might not be dark-adapted

It's quite normal to walk out of a lit room and expect to see objects in the night sky straight away. While it's true that you can see some brighter targets as soon as you head out and even under moderate light-polluted skies, it's not true for the fainter stars and planets - even through a telescope.

Solution

This is a rookie mistake to make and, fortunately, one that's easily corrected with minimal experience. You should wait for your eyes to adapt to the dark before trying to view the night sky. This usually takes around 20 minutes. If you need to use a torch, ensure that it emits red light rather than white.

Option 3

Your telescope might not be aimed at anything

It seems like a silly mistake to make, but you might find that your telescope isn't pointing at anything in particular other than a patch of dark sky, devoid of any bright objects.

Solution

Simply make sure you're pointing your telescope at a bright target, at the very least to check if there isn't something more serious afoot. A good example of one is the Moon, if it's out on the night you have chosen to do your observations and viewing.

What's wrong with my telescope?

Problem

2. My target keeps moving out of view

If your telescope is kept motionless, then - due to the Earth's rotation - objects will move out of view.

If, on the other hand, your telescope moves up and down when you let go of it after aligning, then your instrument could be suffering from poor tube balance or a mount that's unable to support your tube.

Solution

Telescopes from supermarkets or mail order catalogues often suffer from poor mounting. If tightening your mount doesn't work, then replacing it for a mount that's capable of holding your telescope's tube is an option.

Problem

3. I can't find anything

It's easy to forget how small a telescope's field of view can be even if the magnification is low. What this essentially means is that the telescope can only see a small piece of the sky, so it's fairly easy to be spending most of the night trying to line up your telescope.

Solution

If you don't own a GoTo to help you find objects with ease, then you should use your telescope's guide scope or finderscope – provided that this has also been aligned correctly. You can also look along the end of your instrument's tube to get an idea of how it should be aligned in order to view your chosen target. The Moon at your telescope's lowest magnification is your best bet at solving this problem.

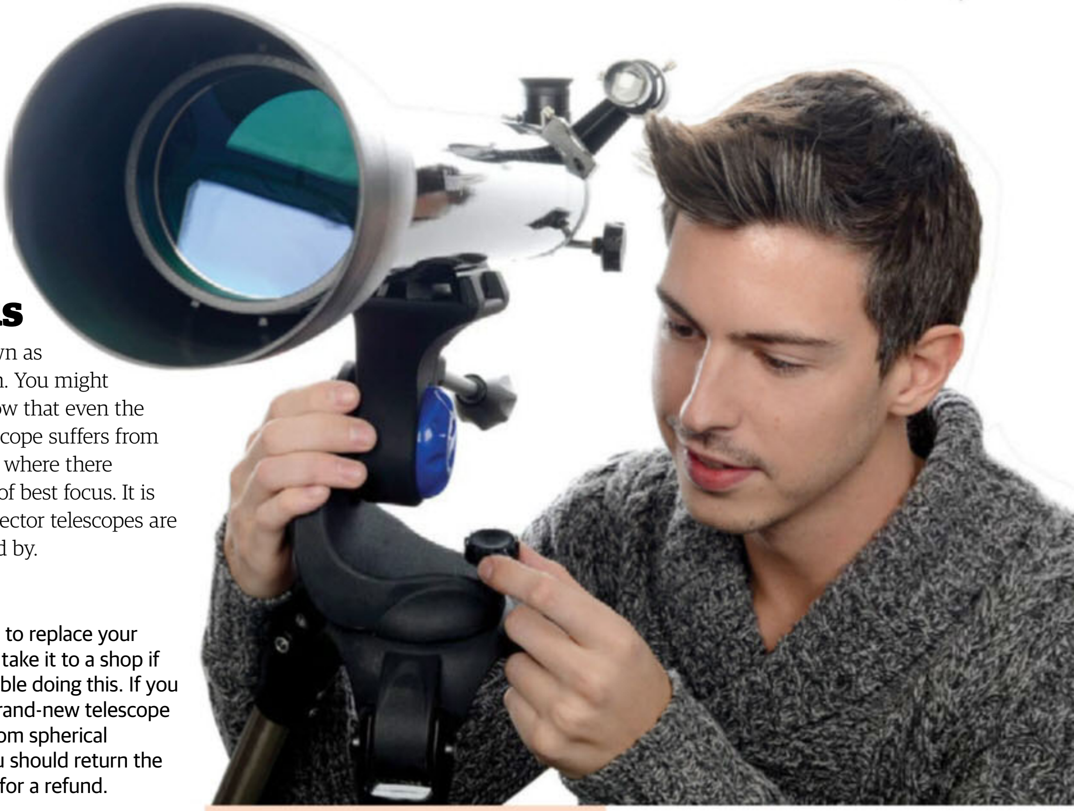
Problem

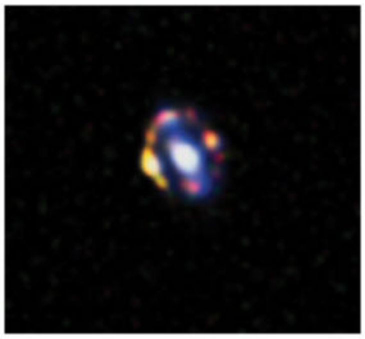
4. I can't get the entire view into focus

This is what's known as spherical aberration. You might be surprised to know that even the Hubble Space Telescope suffers from this same problem, where there seems to be a ring of best focus. It is something that reflector telescopes are particularly affected by.

Solution

The only real cure is to replace your telescope's mirror – take it to a shop if you're not comfortable doing this. If you have purchased a brand-new telescope and it is suffering from spherical aberration, then you should return the instrument and ask for a refund.





Problem

5. Everything looks blurry

No matter what you look at, your target looks like a massive blob with no definite appearance. Whatever you look at through your telescope, it should appear crisp and clear. For example, the Moon's craters should appear well defined while objects such as stars and planets should take a 'point-of-light' appearance.

Solution

The first thing that you should do is to check and adjust the focuser of your telescope to see if you can bring the object into focus. If this doesn't seem to be working, then it could be that your optics are dirty so ensure that your eyepiece is clean. If you've cleaned your optics and you're still having issues, then it could be that the eyepiece that you're using is defective, so try to use a good, well-known eyepiece to see if that fixes the problem.

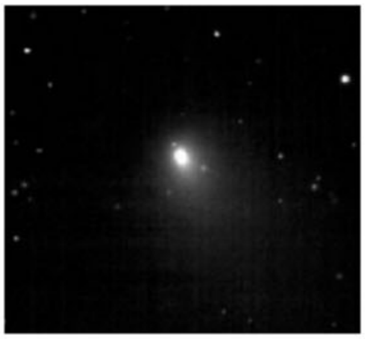
Problem

6. Some bright objects have coloured fringes

Faint blue or violet coloured haloes occur when the blue component of light doesn't focus at exactly the same point as the other colour components. Called chromatic aberration, this usually happens when you look at brighter objects such as the Moon. It's also more common in refractors.

Solution

Colour-fringing, unfortunately, cannot be reduced when you're simply observing through a telescope. The good news is that you can remove chromatic aberration in Adobe Photoshop or a similar photo-editing suite if you're an astrophotographer. If this is something that bothers you, then either go for an apochromatic refractor, reflector or Schmidt-Cassegrain, which should clear up your night sky observation sessions on the fly.



Problem

7. Stars change shape or grow tails

This is known as coma. If your target is changing shape when you focus, then your telescope may be suffering from astigmatism - that's when one or more of the optical components are not perfectly symmetrical. It can also happen when there's a bit of pressure on the optical components.

Solution

You can often buy accessories to correct coma, but you might find that these are quite expensive. If you own a reflector, then you should check that nothing is pushing down on your instrument's mirrors and warping them slightly. Alternatively, if the astigmatism is severe, you should replace the troublesome component. If your instrument is new, then you should return it and ask for a refund from the dealer you bought it from.

What's in the sky?

Moving into Christmas and heading to the new year, the night sky is full of treasures waiting to be observed

Using the sky chart

Please note that this chart is for midnight mid-month and set for 45° latitude north or south respectively.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Open Star Cluster M37

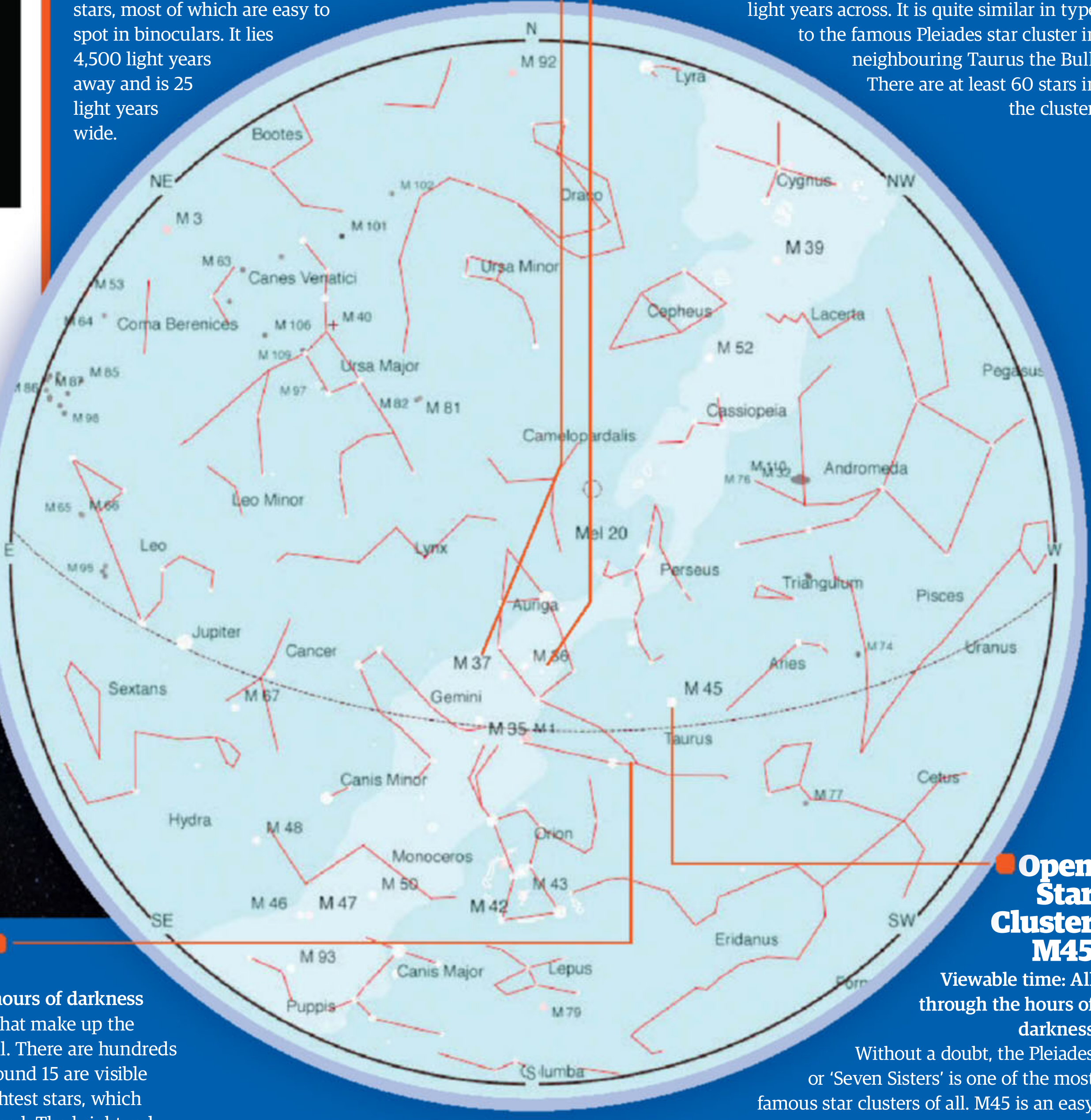
Viewable time: All through the hours of darkness

M37 is the brightest of the open clusters in Auriga. It can be found just outside the body of the constellation. Charles Messier had recorded these clusters in 1764, but they were discovered over a century earlier by astronomer Giovanni Battista Hodierna. This group contains over 500 stars, most of which are easy to spot in binoculars. It lies 4,500 light years away and is 25 light years wide.

Open Star Cluster M36

Viewable time: All through the hours of darkness

Messier 36 is one of three well-known clusters of stars residing in the constellation of Auriga the Charioteer. It's easily seen in binoculars. A small telescope will show many more of the stars in the group. It lies about 4,100 light years from Earth and is around 14 light years across. It is quite similar in type to the famous Pleiades star cluster in neighbouring Taurus the Bull. There are at least 60 stars in the cluster.



Northern Hemisphere

Open Star Cluster The Hyades

Viewable time: All through the hours of darkness

The Hyades is the group of stars that make up the 'V'-shaped head of Taurus the Bull. There are hundreds of stars in the cluster, but only around 15 are visible to the naked eye. It's the five brightest stars, which make the 'V' shape of the Bull's head. The bright red giant star Aldebaran, the 'eye' of the Bull, appears to sit within the cluster but it's not connected, as it's much nearer than the 153 light years of the Hyades.

Open Star Cluster M45

Viewable time: All through the hours of darkness

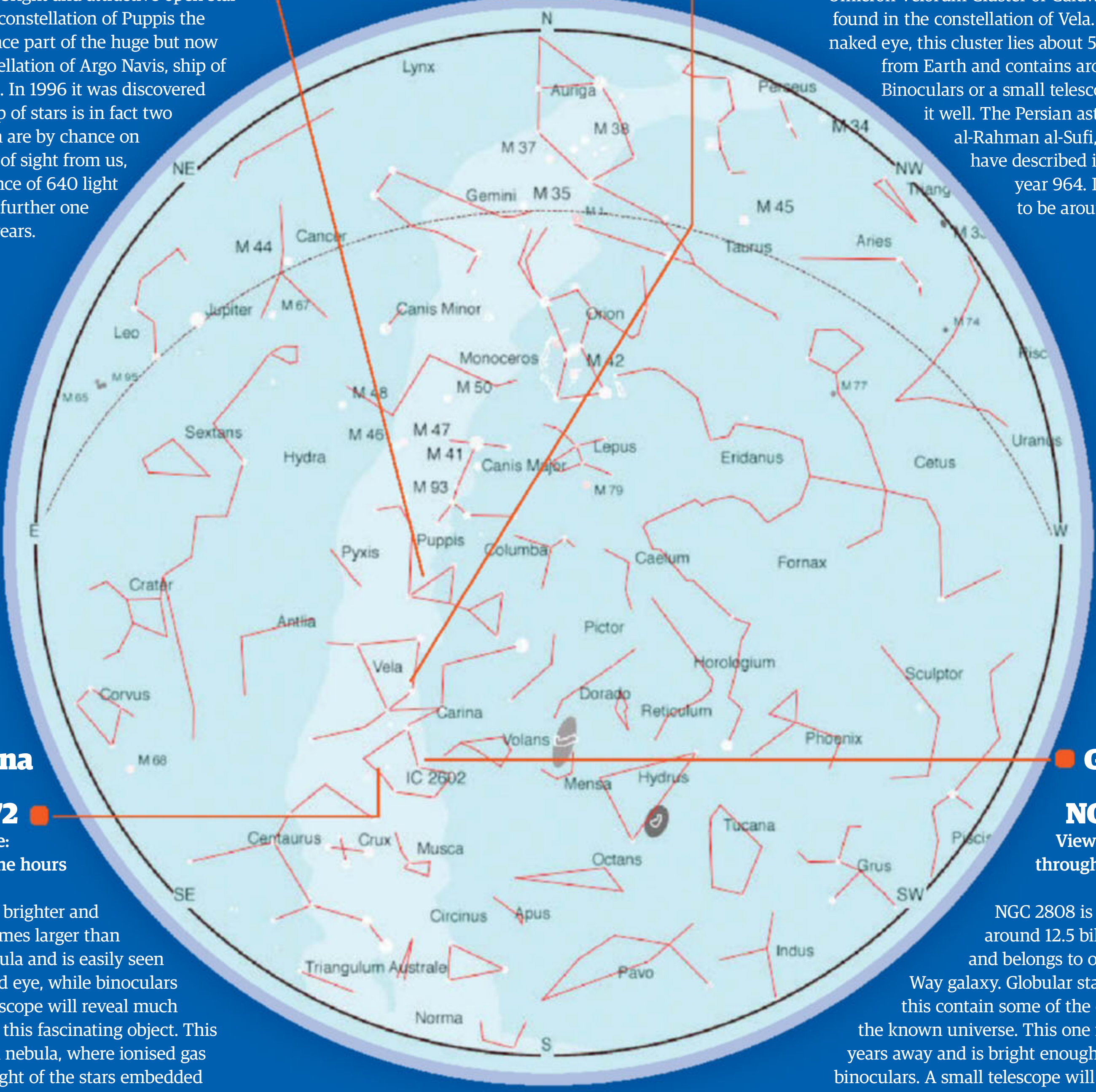
Without a doubt, the Pleiades or 'Seven Sisters' is one of the most famous star clusters of all. M45 is an easy naked-eye cluster positioned just off the shoulder of Taurus. Even from a town, most people can count five or six of its stars. From a darker site, seven or more are possible.

Star Cluster NGC 2451

Viewable time: Through all the hours of darkness

NGC 2451 is a bright and attractive open star cluster in the constellation of Puppis the Poop Deck, once part of the huge but now defunct constellation of Argo Navis, ship of the Argonauts. In 1996 it was discovered that this group of stars is in fact two clusters which are by chance on the same line of sight from us, one at a distance of 640 light years and the further one at 1,170 light years.

Southern Hemisphere



Open Star Cluster IC 2391

Viewable time: All through the hours of darkness

This lovely cluster of stars also known as the Omicron Velorum Cluster or Caldwell 85, can be found in the constellation of Vela. Visible to the naked eye, this cluster lies about 570 light years from Earth and contains around 30 stars. Binoculars or a small telescope will show it well. The Persian astronomer Abd al-Rahman al-Sufi, is thought to have described it in about the year 964. It is estimated to be around 50 million years old.

Eta Carina Nebula NGC 3372

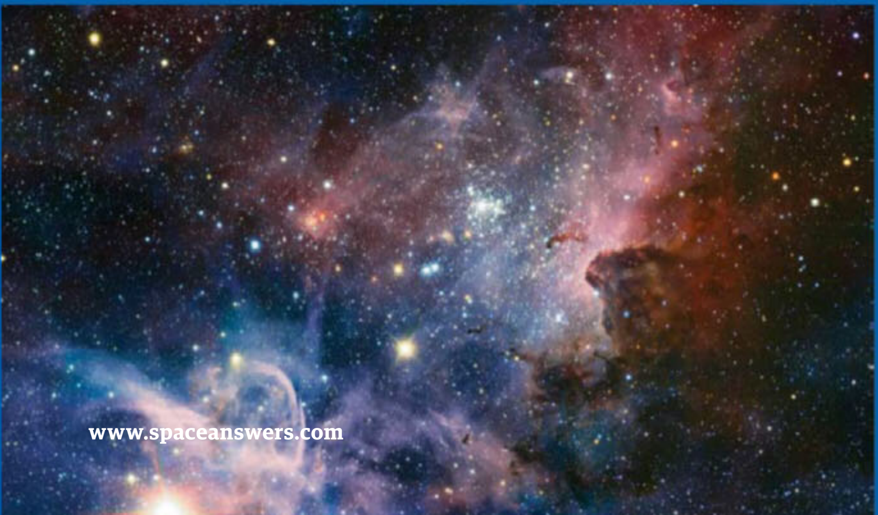
Viewable time: Through all the hours of darkness

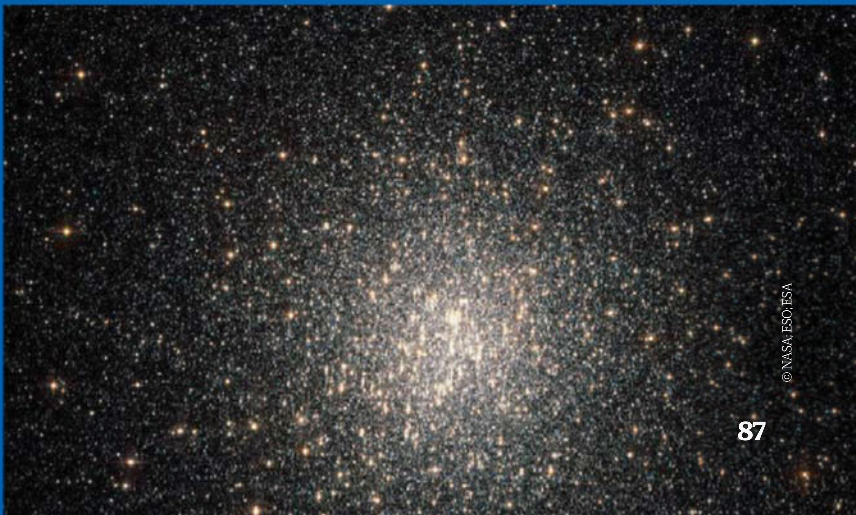
This nebula is brighter and around four times larger than the Orion Nebula and is easily seen with the naked eye, while binoculars or a small telescope will reveal much more detail of this fascinating object. This is an emission nebula, where ionised gas re-emits the light of the stars embedded within as a pinkish glow. It lies at around 10,000 light years distant.

Globular Cluster NGC 2808

Viewable time: All through the hours of darkness

NGC 2808 is thought to be around 12.5 billion years old and belongs to our own Milky Way galaxy. Globular star clusters like this contain some of the oldest stars in the known universe. This one is 31,300 light years away and is bright enough to be seen in binoculars. A small telescope will resolve many of the outer stars and binoculars will show it as a small misty patch of light.





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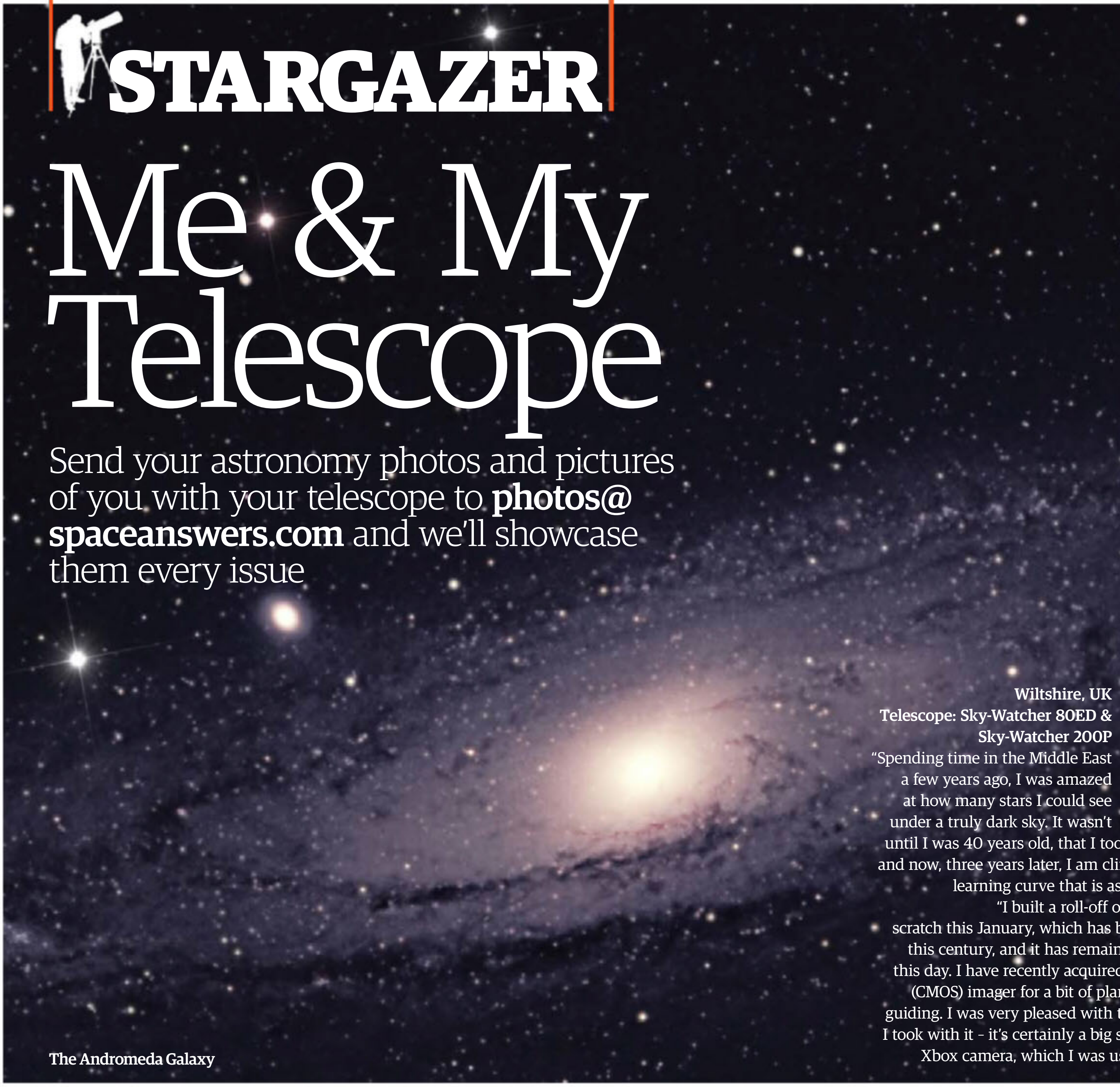
Me & My Telescope

Send your astronomy photos and pictures of you with your telescope to **photos@spaceanswers.com** and we'll showcase them every issue



The Andromeda Galaxy

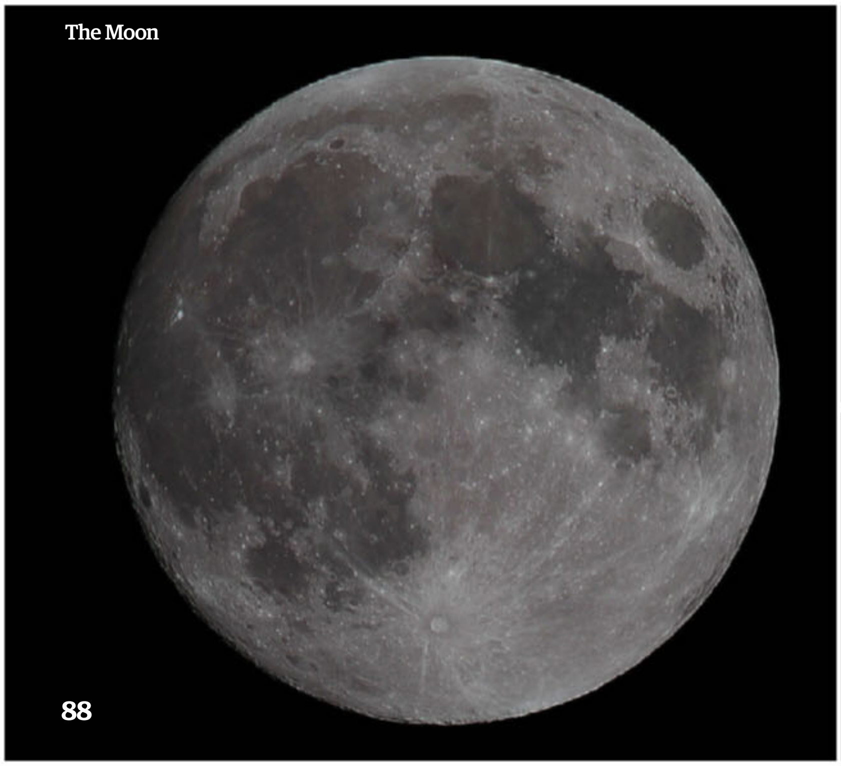
Bob Ford

Wiltshire, UK

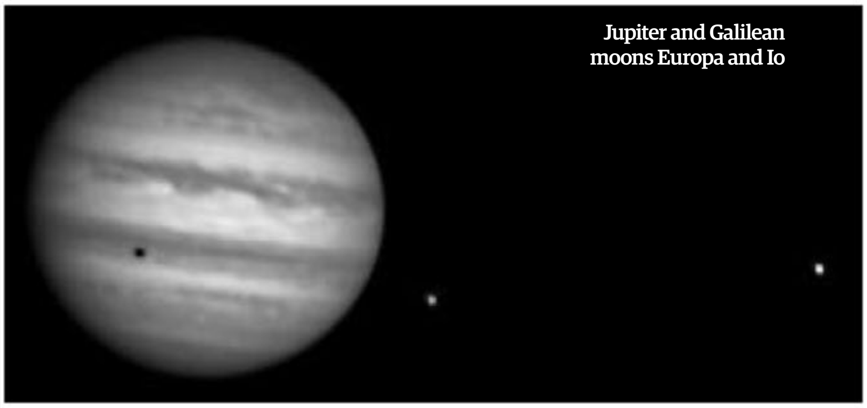
Telescope: Sky-Watcher 80ED & Sky-Watcher 200P

"Spending time in the Middle East a few years ago, I was amazed at how many stars I could see under a truly dark sky. It wasn't until I was 40 years old, that I took up astronomy and now, three years later, I am climbing the steep learning curve that is astrophotography.

"I built a roll-off observatory from scratch this January, which has been the wettest this century, and it has remained dry inside to this day. I have recently acquired the ASI120MM (CMOS) imager for a bit of planetary work and guiding. I was very pleased with the Jupiter shots I took with it – it's certainly a big step up from the Xbox camera, which I was using previously."



The Moon



Jupiter and Galilean moons Europa and Io

The International Space Station (ISS)

Me & My Telescope

James Parker

Northamptonshire, UK

Telescope: Celestron Advanced VX 8"

"Astronomy has been part of my life for a long time. I am always in awe of what is in the night sky and find so many aspects of it intriguing. My love for astronomy began as a child when I was on holiday in Florida where I witnessed the Space Shuttle Discovery lift off from Cape Canaveral. I've been an astronomer since the age of 11 when I got my first glimpse of the Moon through a telescope. I am very excited and proud of the final results of my images. They have given me the determination to seek out more difficult targets to capture."

Luis Figueroa, Jr

New York, USA

Telescope: N/A

"I started looking up at the skies in 2008 when I purchased my first telescope. In that same year I joined the Rockland Astronomy Club in Suffern (New York) and attended many of their sponsored lectures and observing events. After getting my first telescope and seeing the Orion Nebula for the first time, I was just amazed. It was when I attached my Canon EOS 60D to my telescope and took a picture that I became forever astounded. I imaged the 2013 solar eclipse over Long Island. I can't believe how beautiful the colours in the picture are."

Send your photos to... @spaceanswers photos@spaceanswers.com

Stargazing stories

Email the story of how you got into astronomy to **photos@spaceanswers.com** for a chance to feature in **All About Space**

Cristo Sanchez

Location: Texas, USA
Twitter: @askylitRey6
Info: Astronomer for two years
Current rig
Telescope: Orion AstroView 6 EQ reflector
Mount: Orion AstroView EQ Mount and EQ-3M Motor Drive Kit
Other: Orion G3 Deep Space Camera, Orion StarShoot USB II, Nikon D3100 and HTC 8X

"I have been fascinated by the study of astronomy since childhood. Whether it was reading about the cosmos in books or watching documentaries, my eyes were always aimed skyward during the night knowing that so many objects in the universe are visible from my backyard. Since I am in an area of low light pollution, my backyard has become my favourite observing site.

"My father bought an Orion 70mm refractor as my first telescope at the age of 12. After catching glances of the craters that are scattered across the waxing gibbous Moon, I was hooked! My science teacher at the time recognised my interest in astronomy and suggested that I attend a star party at a local nature reserve. With that, she introduced me to the East Texas Astronomical Society, which I soon became involved in and shared my enthusiasm for the universe with like-minded people.

"As the years progressed, I wanted to upgrade to a bigger telescope and hoped to gain the ability to see fainter deep sky objects. At the age of 16, my parents presented me with a new Orion AstroView 6 reflector with an accessory kit and CCD Camera to capture these objects digitally. Since then I have been able to image various objects. Social media groups are a great place to discuss astronomy and share images. My work in astroimaging has led to opportunities such as being asked to give a presentation at a local college and being published in magazines. Although I am still just 17, I believe that this success can continue through hard work and patience. I hope to continue this passion and pursue a career as an astronomer." ●

Cristo's top three tips

1. Get involved

Getting involved with your local astronomical society will help kick-start your hobby in astronomy since you'll be able to talk to seasoned astronomers.

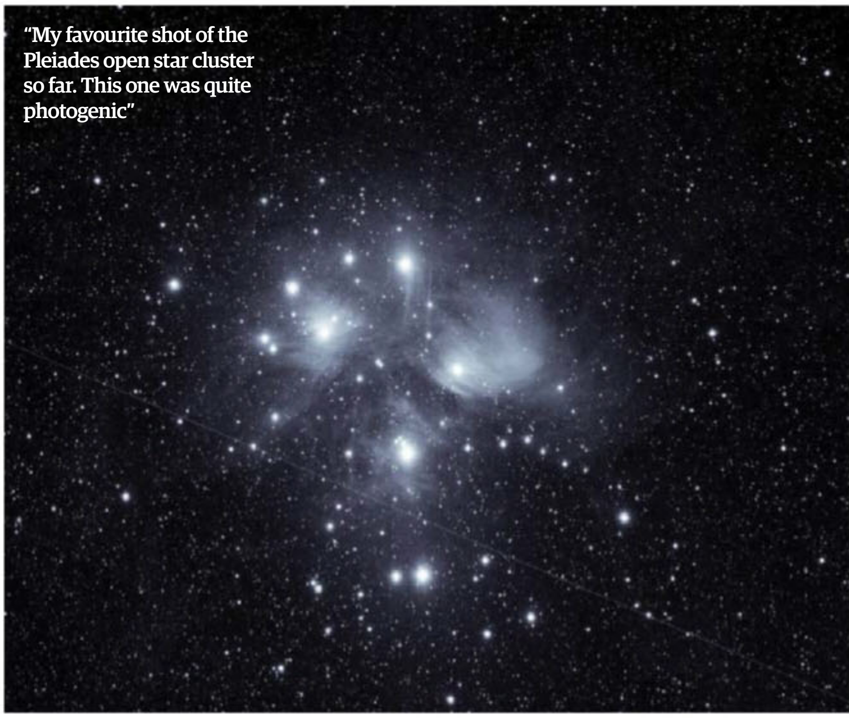
2. Purchase a telescope

Buying a telescope will give you the opportunity to find various objects. For best results, find the biggest aperture possible that suits your budget.

3. Purchase a camera

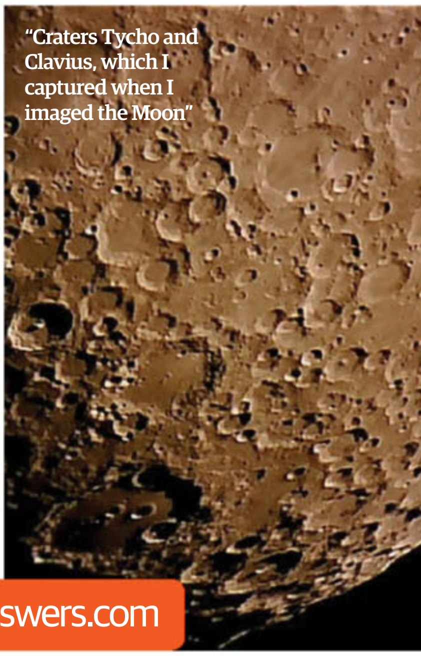
By getting a DSLR or CCD, you'll be able to digitally capture the objects that you view, which is great for those interested in astrophotography.

"The local nature reserve is one of my favourite observing sites"



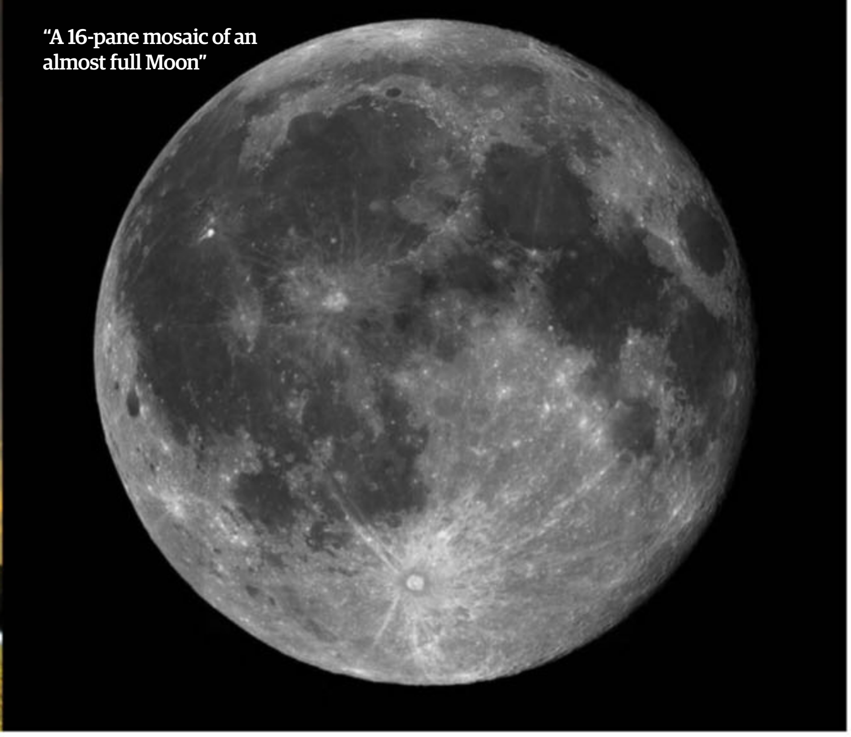
"My favourite shot of the Pleiades open star cluster so far. This one was quite photogenic"

"My setup during an imaging run of Jupiter"

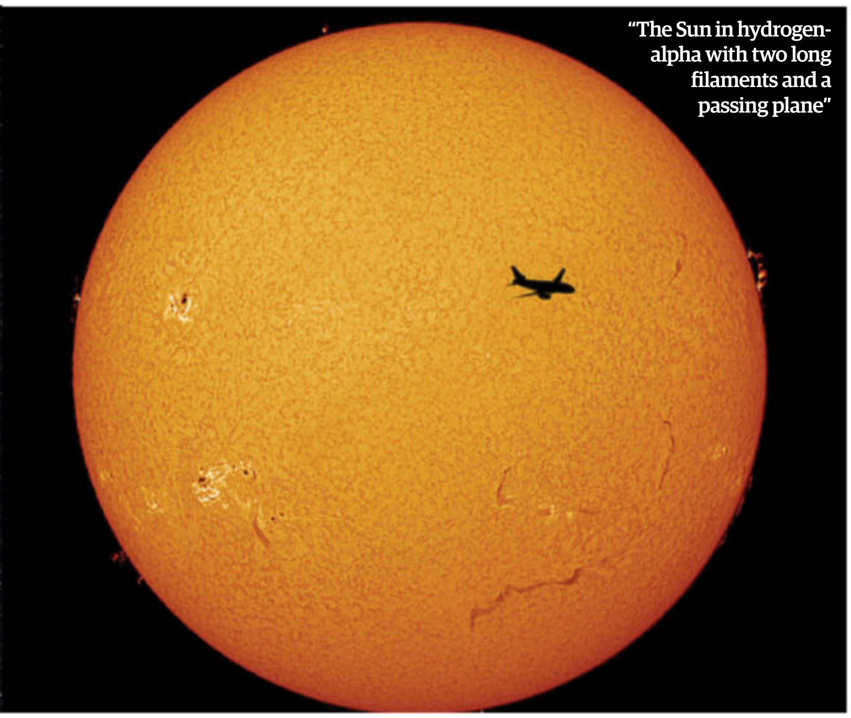


"Craters Tycho and Clavius, which I captured when I imaged the Moon"

Send your stories and photos to... @spaceanswers @ photos@spaceanswers.com



"A 16-pane mosaic of an almost full Moon"



"The Sun in hydrogen-alpha with two long filaments and a passing plane"

"I love low-tech astrophotography! Here's the Moon and Saturn through a spotting scope and digital camera"

Julia Wilkinson

Location: Greater Manchester, UK
Twitter: @astro_jules
Info: Interested in astronomy for over 40 years
Current rig
Telescope: Orion Optics 250mm Newtonian, Coronado SolarMax II 60mm Solar Telescope, Sky-Watcher 66ED APO refractor
Mount: EQ5, Manfrotto 055XPROB with geared head
Other: Astrotrac, Imaging Source DMK41 mono CCD, Canon 40D DSLR, white light solar filter, Helios 8x40 binoculars

"I grew up during the Apollo era when sending humans to explore space seemed routine. I remember watching the Moon walks and wondered what it was like to be an astronaut on our natural satellite. I got my first telescope around that time and used it to observe the lunar surface.

"Nowadays, I like to try my hand at astrophotography. My favourite targets are the Sun and Moon. Our nearest star is different every day and rarely disappoints. I observe and image in both hydrogen-alpha and white light and send my observations to the Society for Popular Astronomy. I also like capturing the different phases of the Moon and love looking out for photo opportunities when the Moon passes close to other astro targets. One advantage of solar and lunar astrophotography is that they are big targets, which means it's easy to see lots of detail with fairly modest equipment. Light pollution isn't a problem either when observing and imaging these objects so I don't need to search out a perfect dark sky.

"Astronomy has opened many doors for me. It led me to the Zooniverse citizen science projects, which allow me to be involved in astronomy research even though I don't have a science background. I help moderate the forums for Moon Zoo, Solar Stormwatch and the Milky Way Project and being part of a large community of astro-minded people gave me the push I needed to study the science I missed out on at school. I now have a couple of qualifications from the Open University, the upshot of which is that I understand much more and that makes the hobby even more enjoyable. I've also had some of my images published and a particular highlight was meeting Sir Patrick Moore at his home a few years ago." ■

Julia's top three tips

1. Find a course

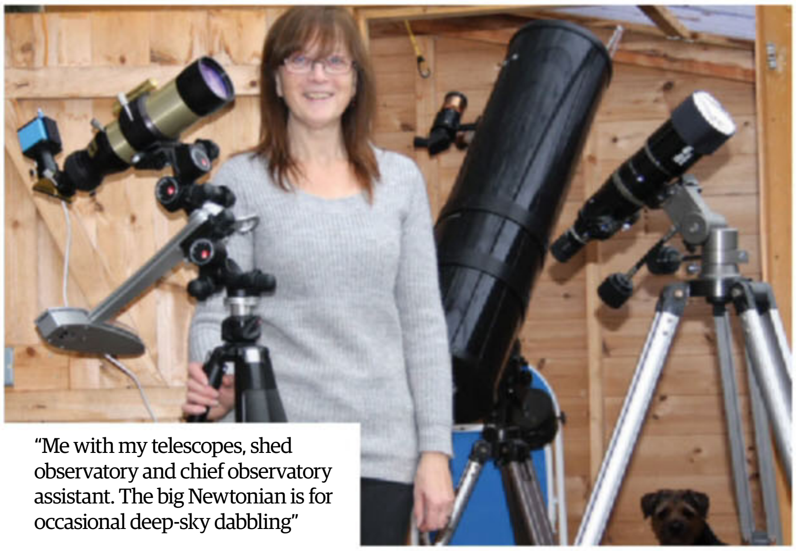
Many are free and a better understanding of the science makes the hobby much more rewarding.

2. Join a club

Whether it's your local club or Zooniverse, having like-minded people to share the hobby with is priceless.

3. Have a go at astrophotography

The Moon's a great target to start with. You'll be imaging other objects before you know it!



"Me with my telescopes, shed observatory and chief observatory assistant. The big Newtonian is for occasional deep-sky dabbling"

Visionary Telesto 1000/114

A good choice for observing a variety of night sky targets but also a great telescope for beginners on a budget

Telescope advice

Cost: £180 (approx. $280)
From: Optical Hardware Ltd
Type: Reflector
Aperture: 4.5"
Focal length: 39"

Best for...

- ? Beginners
- £ Low budgets
- Planetary viewing
- Lunar viewing
- Double stars
- Bright deep sky objects

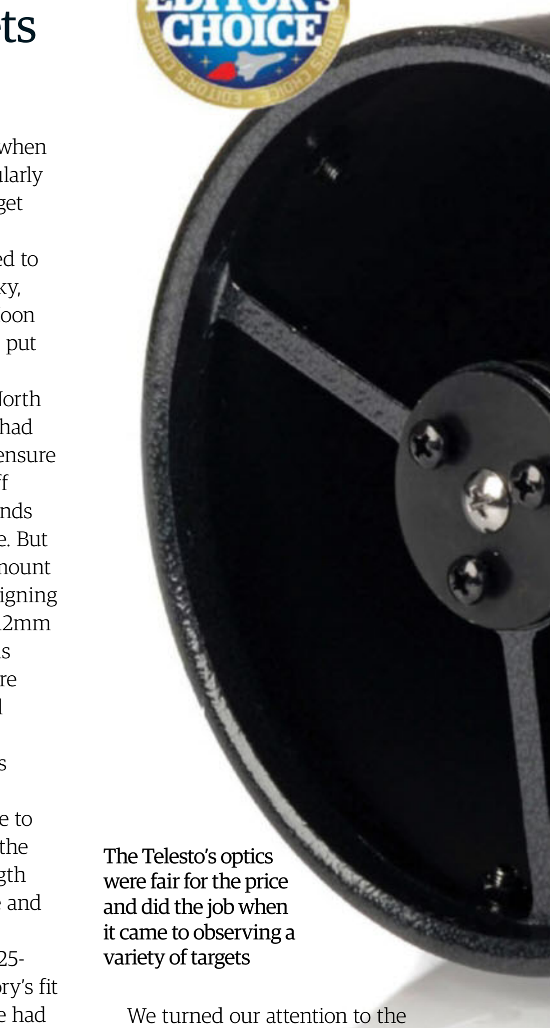
A part of Optical Hardware's Visionary range, the Telesto was surprisingly easy to set up even for a novice astronomer. When it comes to your very first telescope, we always recommend buying an instrument with an alt-azimuth mount rather than one that employs an equatorial mount like this. Equatorial mounts can be complicated to use and set up, and often give an extra bit of heft to the instrument, which can make transporting them quite difficult.

We were pleased to note that the Telesto isn't heavy to carry and certainly isn't difficult to set up since the mount is quite basic. Its assembly is very intuitive and requires no tools to put together. Of course, given such a low price, you shouldn't expect an instrument of high quality and, sadly, the cheap aluminium tripod and flimsy red dot finder let the Telesto down. With its low weight of just nine kilograms (19.8 pounds), we were also worried that a sudden gust of wind could blow the instrument over when we took it out to use on a particularly breezy November night. You do get a complete package for the price, though, with everything you need to get started at touring the night sky, including two eyepieces and a Moon filter. And so, feeling hopeful, we put the Telesto to work.

The equatorial mount had to be tightened in order to stop the telescope from drifting from its target

Turning our attention to the North Star, Polaris, we realised that we had to tighten the locking screws to ensure that the telescope didn't move off target when we wanted to go 'hands free' to look through the eyepiece. But by using the red dot finder, the mount did the job when we set about aligning the telescope. The eyepieces – a 12mm and 20mm, giving magnifications of 83x and 50x respectively – were quite basic. But given the general presentation of the telescope, we weren't surprised. The telescope's tube is also compact despite its 39-inch focal length, which is due to a clever use of mirrors, enabling the instrument to have a shorter length and to make the Telesto portable and easy to carry around.

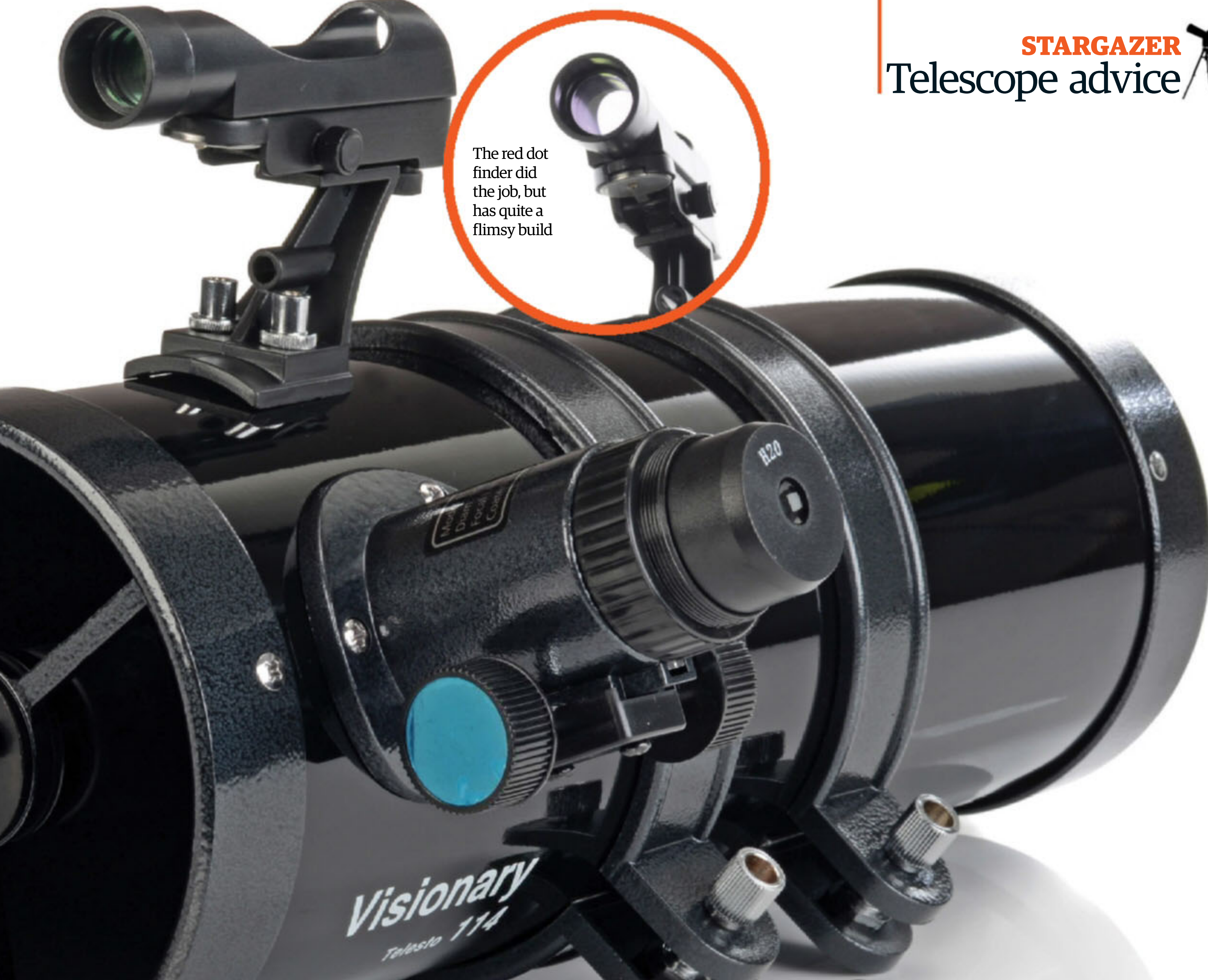
Popping the 20mm into the 1.25-inch eyepiece holder, the accessory's fit was snug but not so tight that we had trouble changing eyepieces. This is good news, highlighting the versatility of the instrument, so any additional accessories purchased at a later date are easily added to it. A half Moon was visible during our observations and we took advantage of its cratered surface. We received good views of our rocky companion, taking in not just impact sites but also the lunar mare, which were defined even more using the supplied Moon filter. With no other Solar System targets – such as Jupiter and Saturn – within range of the telescope's optics at the time, we couldn't truly test the Telesto any further on its planetary viewing ability. However, given its view of the Moon, we believe that it is likely to provide decent sights of these objects too.



The Telesto's optics were fair for the price and did the job when it came to observing a variety of targets

We turned our attention to the brightest star in the sky, Sirius, which dazzled at magnitude -1.46 in the constellation Canis Major. Sadly though, we found that the star began to look distorted, with a fair degree of coma visible roughly 70 per cent out from the centre of the field of view. The inner 50 per cent of the field of view was very good and sharp, while the portion at around 60 per cent provided passable views of Sirius. The Telesto was also capable of splitting double star Mizar, which can be found in the handle of the Big Dipper, into two components when to the naked eye it appears as one – a very good feature for double star enthusiasts.

Grabbing observations of the Pleiades, also known as M45, we detected a pleasing degree of



The red dot finder did the job, but has quite a flimsy build

Two eyepieces - a 12mm and 20mm - were provided, giving beginners to astronomy a complete outfit to explore their hobby

> "We viewed faint diffuse nebulae, which require a telescope of good light-collecting capacity"

nebulosity around the brighter members of this star cluster, which rests in the constellation of Taurus. This is known as the Merope Nebula and a combination of the Telesto's optics and our averted vision meant that the telescope passed the 'light-gathering test' to a satisfying standard. The nebulosity of the Orion Nebula as well as the Trapezium Cluster found at its centre was quite pleasing, too.

Despite the issues with the optics and build, we couldn't complain too much, as what was provided on the whole was very good for the price. Not only that, but the Telesto also allows users to view a variety of targets, including faint diffuse nebulae, which require a telescope of good light-collecting capacity to be visible. So we wouldn't hesitate to recommend this telescope to beginners on a budget. ●

Moon navigation apps

Viewing our lunar companion on your device has never been easier but which is the best app for finding your way around the Moon?

Moon Globe HD

Available on: iOS
Cost: £0.69/$0.99
From: iTunes

This app was incredibly easy to install onto our in-house iPad, so provided you have iOS version 7.0 or later you can be up and running in no time. You can also install Moon Globe HD on iPhone to provide you with even more portability. We've used Moon Globe before but this version certainly lives up to its 'high definition' status and is an improvement on its successful predecessor. What's even more attractive about Moon Globe HD is the very cheap price - given how interactive the app is, it's easily preferable over a paper Moon map. Navigating is easy: spin the Moon with your finger and zoom in or out by pinching the screen.

The images that make up Moon Globe HD were taken by the Clementine mission, which was launched back in 1994, and the app also allows you to view its surface through a variety of instruments at various focal lengths, apertures and magnifications.

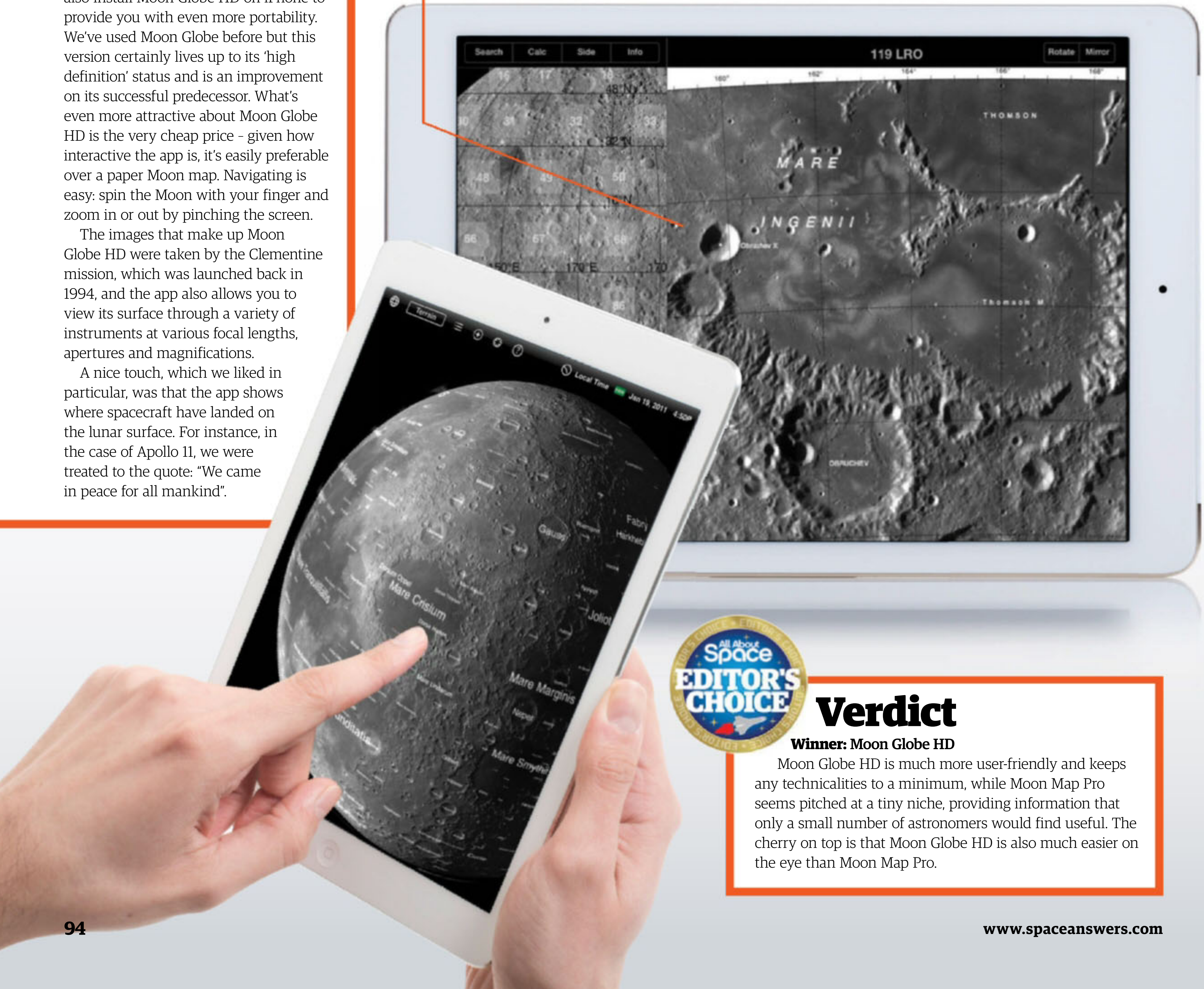
A nice touch, which we liked in particular, was that the app shows where spacecraft have landed on the lunar surface. For instance, in the case of Apollo 11, we were treated to the quote: "We came in peace for all mankind".

Moon Map Pro

Available on: iOS
Cost: £0.69/$0.99
From: iTunes

A lot of information is crammed into Moon Map Pro, which uses maps returned by the Lunar Reconnaissance Orbiter mission - a spacecraft that was launched back in 2009. But we feel this app is a little too complicated for novice astronomers and is geared more towards individuals wanting to get a deeper understanding of the dynamics of our lunar companion.

The interface used by Moon Map Pro was quite clunky in places and a lot of the information provided was so overwhelming that it wasn't until we actually zoomed in to particular objects that we got the breathtaking detail of the craters, mountains and ridges of the Moon. However, despite the amount of data Moon Map Pro gives the user access to, it still managed to operate seamlessly without any freezing or crashing.



Verdict

Winner: Moon Globe HD

Moon Globe HD is much more user-friendly and keeps any technicalities to a minimum, while Moon Map Pro seems pitched at a tiny niche, providing information that only a small number of astronomers would find useful. The cherry on top is that Moon Globe HD is also much easier on the eye than Moon Map Pro.

Astronomy kit reviews

Must-have products for budding and experienced astronomers alike

1 DVD
Live From Space

Cost: £10.00 / $14.99
From: Amazon

If you enjoyed Channel 4's three-part *Live From Space* documentary, produced in collaboration with NASA, then you'll be pleased to know that it's available on DVD and Blu-ray.

As fans of the documentary, which features live broadcasts from the International Space Station (ISS), we were pleased to see that the new release features a good 20 minutes of never-before-seen footage. This includes how space food is prepared, packaged and sent up to the astronauts aboard the ISS, as well as interviews with astronauts such as Mike Massimino, who fixed Hubble, and British astronaut Tim Peake. Notably, one feature concentrates on how astronauts can help aid us with natural disasters such as hurricanes and tsunamis.

And if you've not seen *Live From Space* before, all the more reason to pick up a copy – it's a real insight into what it's like to live in space.

2 Game
Buzz Aldrin's Space Program Manager

Cost: £20.99 / $29.99
From: slitherine.com

Straddling a happy medium between an accessible management sim and informational game, *Buzz Aldrin's Space Program Manager* plays up to its endorsement by dazzling the player with video clips and photos from a classic space era.

Under the hood, a relatively simple simulation sees you take charge of a Fifties space agency, managing budget, recruiting, training, upgrading and building new facilities. And, most importantly, launching new missions.

For history and space buffs, the real charm is in veering from the course of history as much or as little as you like: embarking on projects that in real life never made it off the ground or, as the fictional Global Space Agency (GSA), launching both the famous Sputnik and Apollo missions.

Its turn-based, portable format make it an ideal play for commuting space fans and casual gamers.

3 Accessory
Field Optics Research EyeShield

Cost: £14.99 / $14.99
From: Optical Hardware Ltd

Given the hatred that astronomers feel towards light pollution, we were keen to try out the EyeShield. It claims to minimise the effects stray light has on ruining our view of the night sky.

To look at, there's nothing particularly special about this piece of kit. Whether you choose a pair for your binoculars or a single eyeshield for your telescope, they work in exactly the same way: they attach to your eyepiece and the 'winged' sides blinker you to such an extent that no stray light can affect your night vision or make its way into the optical system of your observing instrument.

Despite the basic design, we felt that the EyeShield worked incredibly well, which we affixed to our in-house telescope when we used it in an area of low to moderate light pollution. What's more, this piece of kit did a very good job of keeping the wind out of our observing eye.

4 Book
New Space Frontiers (Hardback)

Cost: £23 / $35
From: www.zenith-press.com

Given the Space Shuttle's retirement, Piers Bizony's *New Space Frontiers: Venturing Into Earth Orbit And Beyond* is a real eye-opener when it comes to looking at our next move in sending humans into space.

It has the perfect balance of text, artwork and stunning photography, which makes this coffee table book all the more inviting to open and dive into. Bizony certainly does an excellent job of providing an engaging read – especially with quotes from astronauts, private space companies and NASA engineers, which add welcome splashes of colour and a human feel to space hardware.

What we liked most about Bizony's work is that in over 160 pages, he manages to provide a complete read, ensuring that he doesn't scrimp on detail and that even the commercial, non-governmental space exploration companies are featured.

WIN A VISIONARY MIRA CETI TELESCOPE

We've got an excellent entry-level reflector telescope up for grabs this month

WORTH £300

With its six-inch aperture, Visionary's Mira Ceti 150 1400 is the perfect companion to observe a wide range of night sky targets, from planets to deep sky. Now, courtesy of Optical Hardware (www.opticalhardware.co.uk), we're giving this telescope away.

Complete with 25mm and 6.5mm eyepieces to give you magnifications of 56x and 215x respectively, as well as a Barlow lens and Moon filter, this compact and light Newtonian offers good portability. An added bonus is that there's plenty of opportunity to add your own accessories to push the Mira Ceti to the limit. Using a basic equatorial mount, which is included in the package, it also allows you to slew to targets with ease and try your hand at basic astrophotography.

To enter, all you need to do is answer this question:

What was the name of the mission that landed the first humans on the Moon?

A: Apollo 16 B: Apollo 8 C: Apollo 11

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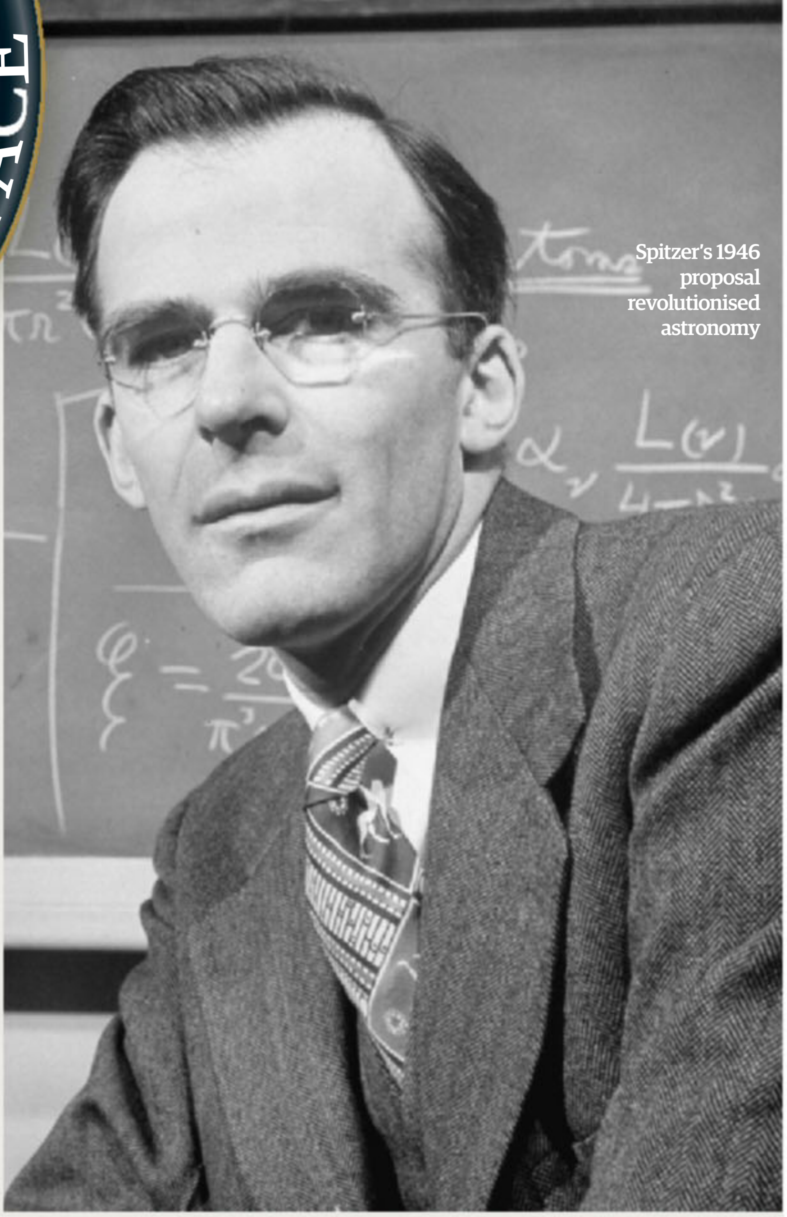
Lyman Spitzer

The man who helped us see space in an entirely new way


Spitzer's 1946 proposal revolutionised astronomy

Born on 26 June 1914 in Toledo, Ohio, Lyman Spitzer may have inherited his eager and curious mind from his ancestor Eli Whitney who invented the cotton gin (a machine that revolutionised the cotton industry).

A natural and passionate student, Spitzer earned a place at Yale University where he studied physics. He also spent a year studying at Cambridge University and finally entered Princeton, gaining a master's degree and a doctorate in astrophysics under the mentorship of the famous astronomer Henry Norris Russell.

He took up a teaching position at Yale in 1939 and, when World War II broke out, Spitzer engaged in underwater sound research as a part of the team that developed sonar. However, it was when he returned to Yale after the war was over that he had the idea that would place him firmly in the history books. In 1946, Spitzer conceived the notion of putting a telescope in outer space, theorising that if the device was in space it would bypass any issues of blurring as a result of being in our atmosphere, thereby producing clearer images than any terrestrial telescope could hope to achieve. He recorded these ideas in the paper 'Astronomical Advantages of an Extra-Terrestrial Observatory'.

Spitzer's proposition was revolutionary for its time. It was over a decade before the first satellite was launched into space and 12 years before the creation of NASA. Undeterred by the opposition he faced, Spitzer was dedicated to his space telescope and worked for the next 50 years of his life trying to make his dream a reality.

The professor's excellence in astrophysics continued to attract attention and in 1947, aged just 33 years old, he was appointed chairman of Princeton University's Astrophysical Sciences department as well as the director of the university's observatory. Under his leadership, it became an important research facility. He fervently studied the interstellar medium and star formation, and his work in this field has led many to hail him as the founder of the study of the interstellar medium.

Spitzer added to his accolades by being appointed president of the American Astronomical Society in 1960. He was lucky enough to be able to watch as the space programme developed and his own concept of putting telescopes in space came closer to reality than ever before. In 1962, he designed an observatory that could orbit the Earth. This very same observatory later became the Copernicus satellite, used by NASA between 1972 and 1981. While many of his peers were opposed to the cost of Spitzer's space telescope, he worked tirelessly to convince the academic community and Congress that it was a worthwhile endeavour, and he finally achieved it in 1968 with the Orbiting Astronomical Observatory.

Although he was decorated with awards for his achievements, Spitzer didn't slow down and he managed to convince both NASA and Congress to begin work on the Hubble Space Telescope in 1975. Because of Spitzer's efforts, Congress agreed to fund the construction of the telescope in 1977. In 1990, 44 years after Spitzer first envisioned the existence of a telescope in space, the Hubble Space Telescope was launched. To this day Spitzer's creation has delivered stunning and breathtaking images that were previously unfathomable, helping us to understand space and leading to countless new discoveries.

Lyman Spitzer worked tirelessly until the day he died. When he passed away suddenly on 31 March 1997 aged 82, he had just finished discussing exciting new ideas and studying the results from the Hubble telescope. In 2003, NASA launched a brand-new observatory into Earth's orbit, named the Spitzer Space Telescope in honour of the man whose vision and determination made it all possible. ●

All About Space

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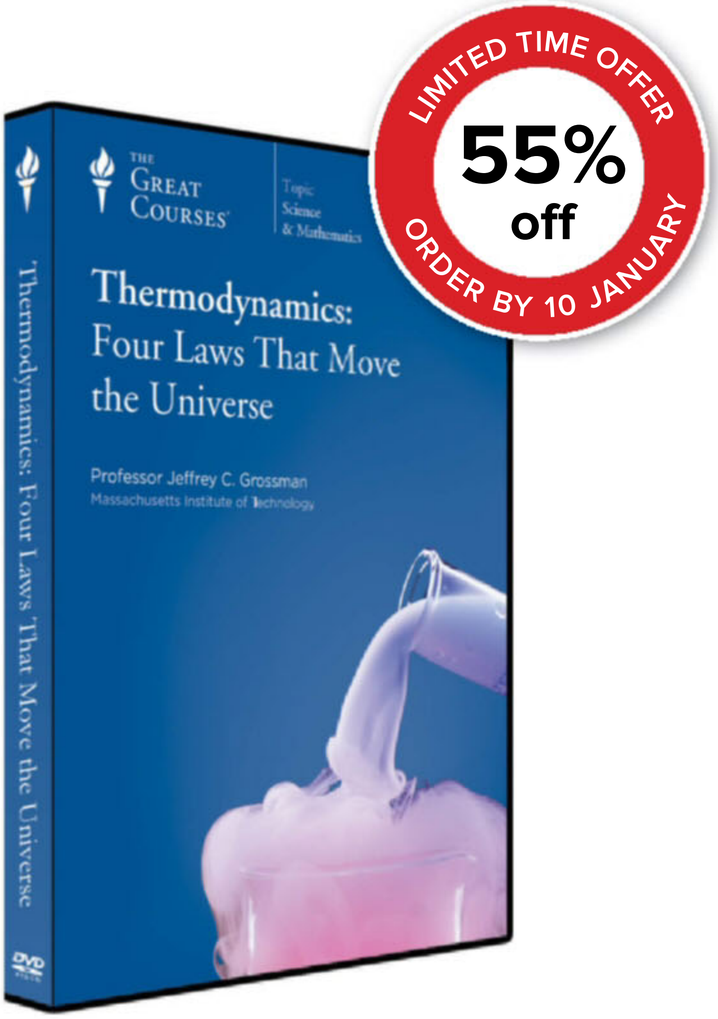
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